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Optimization of costs and benefits in Inter TSO Compensation mechanism

Ivan Androcec [*1], Slavko Krajcar [*2], Ivar Wangensteen [*3]

[*1] *Hrvatska elektroprivreda d.d., Ulica grada Vukovara 37, Zagreb, Croatia*
ivan.androcec@hep.hr

[*2] *Faculty of Electrical Engineering and Computing, Unska 3, Zagreb, Croatia*
slavko.krajcar@fer.hr

[*3] *NTNU, Department of Electrical Power Engineering, Trondheim, Norway*
ivar.wangensteen@elkraft.ntnu.no

Abstract— **Purpose of this paper is to specify the benefits in Inter TSO Compensation mechanism. The intension is to contribute to the future solution for transit in the European Power Market. Cross-border trading is influenced by several mechanisms (congestion management, transit, tariffs, investment) which need to be examined from technical and economical point of view. All mechanisms are interconnected and represent an extensive and complicated set of problems. Cross border exchange has direct economic benefits leading to increased competition, increased market liquidity, stabilized prices and increased security of supply.**

In the Regulation 714/2009/EC and Guidelines 774/2010/EC (838/2010/EC) for ITC there is no clear definition of the benefits-concept and elements that should be considered. We will discuss some of the principles that are suggested and/or applied and study possible consequences. Some illustrations and calculations were done in MATLAB based on full AC optimal power flow. The balance between benefits and costs are analyzed depending on inter-area conditions. In the end we have proposed general algorithm for compensation of losses which include calculation of benefits with detailed principles: real losses with transits minus estimated losses without transits minus estimated benefits with transits. These principles could be applied to any future solution for transit.

I. INTRODUCTION

Presently there are one or more TSOs for each country in Europe. As long as we have more than one TSO, we are facing the problem of how to divide costs and revenues among the involved companies. The Inter-Transmission System Operator Compensation (ITC) mechanism shall provide for compensation for the costs of hosting cross-border flows of electricity including providing cross-border access to the interconnected system. The reason for introducing ITC was straightforward: The tier system of cross border tariffs was destroying all attempts to develop a reasonable cross border trade, and it was important to ban the further use of cross border tariffs. But as that would significantly reduce TSO income, and increase the “tariff burden” of domestic grid users unless compensated, the idea of side payments came up. Side payments are well known from cooperative game theory, and are intended to “correct” the economic outcome after normal transactions. Efficient pricing schemes will not necessarily lead to a distribution that is recognized as fair by all participants. Thus if participants cooperate, it is possible to negotiate side payments in order to provide an agreeable distribution.

Power exchange can cause increased flow and losses, but can also be beneficial and reduce losses inside the “hosting” country [2]. One reasonable hypothesis is that the major benefits of hosting cross border flows are related to congestion rent and reduced costs to security of supply maintenance. It must be regarded unfair if transit via a third party’s grid causes extra costs that must be covered by the customers on that grid. On the other side, it is important to take the benefits of trade into account when designing the ITC arrangement, but none of the negotiated methods (With-or-Without-Transit, Average Participation, Marginal Participation, Improved Modelling for Infrastructure Cost Allocation) include this. The methods do not take into account the establishment of exchanges and the interactions in trade with a price response. In an efficient power system the less expensive generation resources should be used first.

To have more benefits from electricity trading new investments are needed, but we have shown that sometimes it is not clear if we got the right incentive (interaction of congestion rent, transit and tariffs) [4]. An ideal compensation scheme would give the optimal incentive to a country to expand its network. By investing in a highly needed transmission line, transit (and compensation) would increase, and this could pay for the line in addition to the local benefit of the line. The costs will be established based on forward looking long-run average incremental costs, taking into account losses, investment in new infrastructure, as well as the cost of existing infrastructure. Basis for the calculation of transit should be the measured physical flows. Benefits that a network incurs as a result of hosting cross-border flows shall be taken into account to reduce the compensation received. The major benefits of hosting cross border flows are related to congestion rent and reduced costs for maintaining security of supply. Other benefits are related to the trade of electricity, e.g. payment to power exchange or traders.

ITC arrangements should still be neutral with respect to transactions between market participants. It should be transactions between TSOs not affecting the participants and not affecting the load flow.

The transit through a country can be broadly defined as that part of the flows over the grid of a country that is unrelated to the activity of the agents inside the country - imprecise definition of transit. Transit is defined as the minimum value of import and export over different lines for a given area, e.g. if import to an area is 250 MW and export is 100 MW, then transit is 100 MW – see fig. 1.

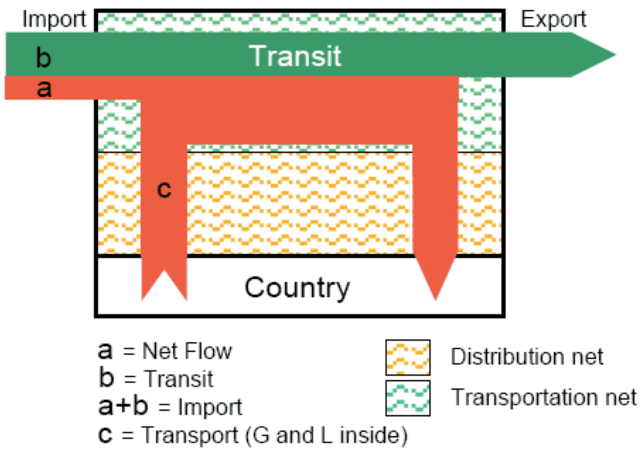

Fig. 1: Illustrative graph of the definition of transit [2]

The regulation requires taking into account the costs but also the benefits of transit flows. The simpler models have not taken into account the possible benefits of cross border flows but they have rather considered transits proportionally to the internal flows in a country independently of whether the transit flows have reduced the internal flows or aggravated them. More complicated models have tried to address this explicitly so that benefits can also be accurately calculated. Agreement between TSOs as to how to specify such models has not been possible. The benefits of transit flows have only been considered in the context of the impact physical flows have on the host network. Commercial benefits to TSOs linked to these physical flows have not been included in the analysis although such benefits can be considerably higher than the costs incurred hosting the flows. For example Switzerland, Denmark and Germany collected 35, 80 and 316 million euros congestion rents per year respectively (data for 2007). A substantial portion of this can be attributed to transit flows resulting from commercial transactions [3]. Although many potential methodologies have been studied for the ITC mechanism, there has been no agreement among TSOs and regulators on a single method. The additional complexity needed to estimate benefits, including any resulting loss of transparency, can only be justified if accuracy really increases and if outcomes from the model are not highly sensitive.

As discussed previously, transits can be of benefit to the host system. Such benefits, for example, as a result of netting effects, are implicitly taken into account in the more sophisticated methodologies such IMICA. Where these can be accurately modelled these should be included in any ITC mechanism. Transit flows can also create significant congestion rents for the hosting TSO. These congestion rents are partially a result of commercial transactions which are the main cause of the physical transit flows. Congestion rents which result from such commercial transactions can be calculated in a manner analogous to the calculation of physical transit flows. Such congestion rents clearly form a benefit for the host network.

Valuing losses based on average EU prices recognizes that power flows on any part of the system can affect the rest of the system. However, this does not reflect the true value of electricity where it is lost. Geographic variations in the price of electricity represent the local value of electricity. It is more accurate to value losses based on the value of electricity in those areas where losses are incurred, and, insofar as possible, at the time they are incurred. This also captures the benefits/costs of losses most accurately. It therefore fulfils two of the three criteria best. Moreover, there is no obvious loss of transparency from taking local market prices as opposed to averaging a series of local prices. Nodal prices represent optimal short term price signals to market participants in a competitive electricity market [1].

II. Regulation 714/2009 & Guidelines 774&838/2010

The ITC mechanism was first implemented with nine ITC Parties in 2002. At the beginning of 2004, the total number of ITC parties increased to twenty. The number of countries participating in the voluntary scheme had increased to 32 by the end of 2009. It is currently a voluntary agreement among participating TSOs. Where relevant, regulatory authorities have reviewed TSO involvement and have provided data on allowed transmission network costs.

The calculation of compensation had two main components: an infrastructure asset cost element to compensate for the cost of hosting cross-border flows, and a transmission losses element based on the with-and-without-transit (WWT) model. In the WWT-model, losses are calculated on each TSO's transmission grid in a load flow situation with transits and in a load flow situation without transits. The level of infrastructure payment was based on the regulated cost asset value of the infrastructure used to host cross-border flows, and the amount of cross-border flows between the participating TSOs. Contributions from participating countries were calculated based on cross-border flows between these countries. The contribution from perimeter countries was €1.4/MWh multiplied by the sum of scheduled flows to / from participating countries. The compensation amounts for a participating TSO during 2007, 2008 and 2009 vary from paying approximately €55 million to receiving about €60 million. During these years, the value of the compensation fund has been around €350 - 400 million, depending on the cost of the horizontal network and the amount of flows [3].

The European Commission proposals to the Committee consisted of two Commission Regulations, one under Regulation 1228/2003, and a second under 714/2009 that has applied from 3 March 2011 and would reflect the institutions established by the 3rd Package [7]. The guidelines relating to Inter-TSO compensation and a common regulatory approach to transmission charging were adopted as Commission

Regulation (EU) No 774/2010 on 2 September 2010 [8]. The annual cross-border infrastructure compensation sum shall be €100.000.000.

Transmission system operators shall receive compensation for costs incurred as a result of hosting cross-border flows of electricity on their networks. The compensation shall be paid by the operators of national transmission systems from which cross-border flows originate and the systems where those flows end. Compensation payments shall be made on a regular basis with regard to a given period of time in the past. Ex-post adjustments of compensation paid shall be made where necessary, to reflect costs actually incurred. The magnitude of cross-border flows hosted and the magnitude of cross-border flows designated as originating and/or ending in national transmission systems shall be determined on the basis of the physical flows of electricity actually measured during a given period of time.

The costs incurred as a result of hosting cross-border flows shall be established on the basis of the forward-looking long-run average incremental costs, taking into account losses, investment in new infrastructure, and an appropriate proportion of the cost of existing infrastructure, in so far as such infrastructure is used for the transmission of cross-border flows, in particular taking into account the need to guarantee security of supply. When establishing the costs incurred, recognised standard-costing methodologies shall be used. Benefits that a network incurs as a result of hosting cross-border flows shall be taken into account to reduce the compensation received.

Compensation for losses incurred on national transmission systems as a result of hosting cross-border flows of electricity shall be calculated separately from compensation for costs incurred associated with making infrastructure available to host cross-border flows of electricity.

The annual cross-border infrastructure compensation sum shall be apportioned amongst transmission system operators responsible for national transmission systems in proportion to:

(1) transit factor, referring to transits on that national transmission system state as a proportion of total transits on all national transmission systems;

(2) load factor, referring to the square of transits of electricity, in proportion to load plus transits on that national transmission system relative to the square of transits of electricity in proportion to load plus transit for all national transmission systems.

The transit factor shall be weighted 75 % and the load factor 25 %.

III. Examples of Transit in Four Area Model

With several power systems connected, the power flow can be distributed in disproportion to the trade, as illustrated in Figure 2. Area A is buying power from area B (Q_{AB}), but the actual power flow is from area B, via C and D and further to area A. This trade involves four areas, and the part of the power flow through areas C and D can be referred to as a *loop flow*. In the example above, an attempt to force the entire power exchange, Q_{AB}, directly from B to A would most probably result in higher electrical losses. However, loop flows may contribute to network congestions in the affected areas or cause limited possibilities for power exchange within or between areas C and D. The definition and discussion of loop flows are therefore seen to be very closely related to power transit. In the situation illustrated by the example above the areas C and D are candidates to be compensated for the power transit resulting from the loop flow.

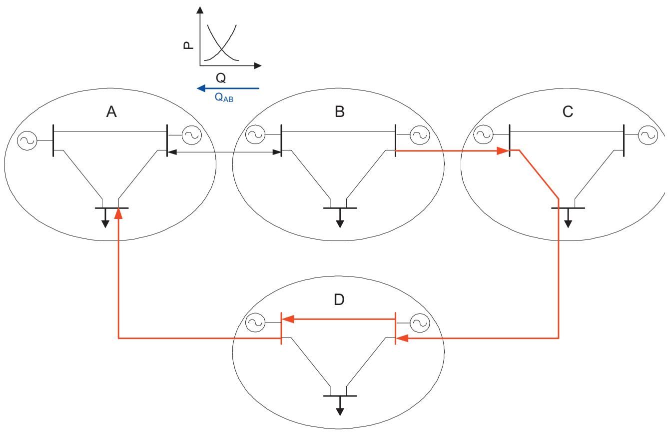

Fig. 2. Example of transit due to loop flow

In the presented case (fig. 3), area 4 is buying power from area 3, but the actual power flow is from area 3, via 1 and 2 and further to area 4. This trade involves four areas, and the part of the power flow through areas 1 and 2 can be referred to as a loop flow. The existing ITC mechanisms failed to reflect actual conditions in transmission networks and failed to set a fair compensation for the use of the grid.

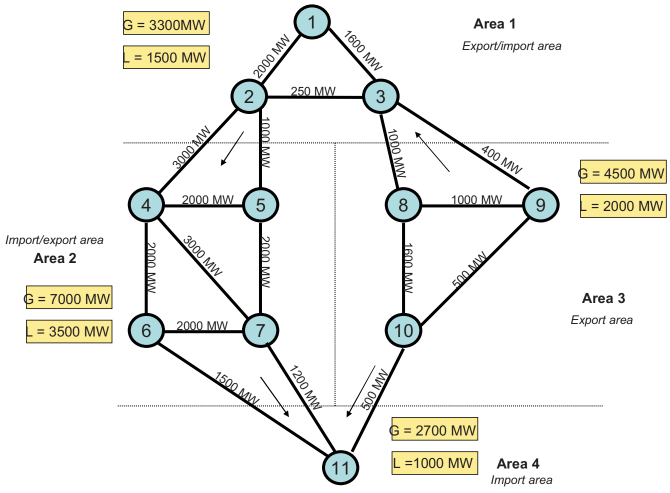

Fig. 3 Base case for OPF calculation made in MatLab/Matpower

The benefits from transit should not be strictly related to the physical conditions in the grid. In addition, it is possible for the countries to profit by buying at a low price at one side of the border and selling at a higher price at the other side. The models might describe the physical situation pretty well, but they do not include the benefits. Compensation should in general take into account these benefits:

Compensation = Real losses with transit – estimated losses without transit – estimated benefits with transit.

Example 1: Due to positive power flows of transit some power plants don't need to work in case of power system stability/security.

Benefits in terms of improved security of supply are one of the obvious advantages of exchange arrangements between TSOs. One can either improve security of supply within given cost limits or one can reduce costs and keep the security level constant. In many cases it will be a combination of both. In any case it will be a benefit. How costs and benefits are divided between the parties is subject to negotiation in each individual case and it is therefore difficult to draw general conclusions.

In this example (see Table I) benefit is reduction of power plant costs based on TSO order. Power plant can in that case offer more on power market; reserve capacity can be split between more areas. The area with the largest generating units and the area with the most unreliable units will benefit most.

TABLE I
BASE CASE – WITH-OR-WITHOUT TRANSIT

Area	Node	P (MW)	P_T (MW)	p (EUR/ MWh)	p_T (EUR/ MWh)	Δ_P (EUR /h)
1	1	1000	1000	19	23	4000
	2	525	763	21	24	7287
	3	0	0	18	24	0
2	4	1233	1277	24	25	2333
	5	1163	818	29	25	-13277
	6	761	747	26	26	-364
	7	361	281	27	26	-2441
3	8	784	621	25	23	-5317
	9	419	798	18	22	10014
	10	804	1085	19	22	8594
4	11	1000	700	36	26	-17800

Benefit of transit (and cross-border exchange) is in area 2 for consumers – some generators are not working as in non-transit case:

$\Delta_P = P_T * p_T - P*p$ (MW * EUR/MWh = EUR/h)

Benefit of cross-border exchange is in 1 and 3 for generators but not for consumers. Benefit of cross-border exchange is in 4 for consumers but not for generators. Transit in area 1 is 238 MW and transit in area 2 is 51.

Transit = minimum of import/export

The balance in the four areas is:
Area 1: 262,3 MW
Area 2: -410,17 MW
Area 3: 530,77 MW
Area 4: -300 MW

Total losses with transit are 89 MW, and without transit are 51. So compensation should be for loss of 38 MW mostly in transit areas 1 and 2. But area 2 needs to include evident benefit of transit. The total benefit of regional market is evident.

It is assumed that the TSO makes his revenue both from the generation units and the consumption units through the tariffs. His costs are due to transmission losses. These have to be bought at the reference price (24 EURO/MWh).

Example 2: Congestion costs on borders are increased due to transits

Benefit in this case is part of revenue from congestion cost. Congestion rent should be taken into account for covering costs due to transit in area 1 and area 2. This should be taken from main congestion between areas 3 and 4, but also from other congestions on other interconnected lines.

TABLE III
REDUCTION OF INTERCONNECTOR CAPACITIES ON ¼ BETWEEN AREAS

Area	Node	Pc (MW)	P_T (MW)	p_c (EUR/ MWh)	p_T (EUR/ MWh)	Δ_P (EUR /h)
1	1	1000	1000	23	23	0
	2	794	763	25	24	-1538
	3	0	0	24	24	0
2	4	1331	1277	25	25	-1350
	5	858	818	26	25	-1858
	6	810	747	27	26	-2448
	7	326	281	27	26	-1496
3	8	571	621	23	23	1150
	9	752	798	22	22	1012
	10	928	1085	20	22	5310
4	11	700	700	28	26	-1400

As shown in Table II it should be noticed that Area 1 and Area 2 are the only Areas who receives a positive effect from the bottleneck scenario. This is an interesting discovery because it gives the TSOs in Area 1 and 2 incentives to restrain from expanding cross-border capacity. Because they also receive compensation due to transit their compensation needs to be reduced with part of congestion income. From this it seems obvious that no incentives to expand cross-border capacity will be obtained.
Losses in transit are reduced to 70 MW (as expected). Total Inter-tie Flow are reduced 250 MW. Costs due to congestion are higher for 517 EUR/MWh for the Region.

Optimal power flow results between areas are:

	congestion	base (transit)
Area 1 – 2	363	471
Area 1 – 3	-87	-219
Area 2 – 4	160	62
Area 3 – 4	149	259

There is an obvious loss for the whole region due to decrease of interconnector capacities.

Example 3: Relationship between costs for grid (tariffs), congestion costs and transit compensation

Total TSO revenue =
Revenue from generation units +
Revenue from consumptions units –
Costs for transmission losses

In Table III we have shown how internal congestion (which influence on grid tariff) can impact on congestion costs whit transit included. Notice that the TSO in a region with positive net balance will increase the profit from higher price (region 1 and 3), while the TSO in a region with negative net balance will reduce the profit when the reference price rises (region 2 and 4. A nodal pricing system based on point tariffs and one single hub (one common system price) for several TSOs, leads to problems for the distribution of revenue and costs among the TSOs.

TABLE III
REDUCTION OF INTERNAL CONNECTOR 4-7 TO 500 MW - INTERNAL CONGESTION

Area	Node	P_I (MW)	P_T (MW)	p_I (EUR/ MWh)	p_T (EUR/ MWh)	Δ_P (EUR /h)
1	1	1000	1000	23	23	0
	2	686	763	23	24	2534
	3	0	0	24	24	0
2	4	1134	1277	23	25	5843
	5	819	818	25	25	-25
	6	776	747	26	26	-754
	7	466	281	29	26	-6208
3	8	611	621	23	23	230
	9	789	798	22	22	198
	10	1097	1085	22	22	-264
4	11	700	700	28	26	-1400

Results of this case: changes on generators in 1 and 2 (transit areas), in area 4 almost no change, and in area 4 change on customer side (more costly). Even if we increase interconnected capacity 10-11 for area 4 will be almost no change due to optimal power flow solution. It is also shown how internal congestion has an impact on congestion on borders and in total on the condition in whole regional market.

If we include fair inclusion of benefits as we have shown in example 1 and 2 TSOs revenues should be different from current procedure. It might be an interesting study to see how a bottleneck situation will affect the compensation allocation in a more realistic grid system.

IV. DISCUSSION ON INTER TSO COMPENSATION

"Declared transit" of electricity means a circumstance where a "declared export" of electricity occurs and where the nominated path of the transaction involves a country in which neither the dispatch nor the simultaneous corresponding take-up of the electricity will take place.

In the Regulation [7] cross-border tariffs were banned in order to increase the efficiency of the Internal Electricity Market (IEM). But, since it would significantly reduce the TSO's income, and increase the "tariff burden" of domestic grid users unless compensated, the idea of side payments came up with the intention to compensate for network use between TSOs. A voluntary ITC agreement was introduced in 2002 to replace the cross border tariffs. The new voluntary agreement for 2008-2009 is implemented by use of WWT method.

The ITC Guidelines and Guidelines on Transmission Tariffication have been adopted [8] & [9]. Difficulties concerning the appropriate ITC scheme have postponed the process. Different principles for ITC were considered in the Nordic region and on the Continent. The procedures have been subject to a lot of discussion and several revisions have been made. The ITC arrangement is still under discussion although there is a compromise for use of WWT method.

The regulation contains weak points. Hosting has no clear definition and the transit arrangement does not promote an efficient market. The physical flow and the trade contract are not necessarily corresponding. The volume produced to fulfil a bilateral contract will be consistent with physical laws and follow a certain route dependent on impedances. Furthermore, the flow is affected by generation volume and load of other participants. It is difficult to map the origin and end of a cross-border flow. The national border and the TSOs network do not always demarcate the origin and end of power flows. The hosted power cannot be measured and the contract volume cannot be used for host charging. To charge a TSO means to address all the participants through the tariff. These participants have no benefit of a bilateral contract. Charging all participants for a bilateral contract seems unreasonable. The two commercial participants in a bilateral contract will get the benefit of a prioritized right and eliminate other participants on the transmission line.

The Regulation provides no clear definition of the benefits-concept and elements that should be considered. Power exchange can cause increased flow and losses, but can also be beneficial and reduce losses inside the "hosting" country. One reasonable hypothesis is that the major benefits of hosting cross border flows are related to congestion rent and reduced costs to security of supply maintenance, as we have shown in previous section.

There is also a question of compatibility with future goals in an integrated electricity market, compared to today's status of regional electricity markets. ITC arrangements should be neutral with respect to transactions between market participants. Transactions between TSOs should not affect the participants and the load flow. ITC arrangement should have no operational implications.

Important questions are whether ITC compensation will give incentives and promote improvements in operational efficiency and investments. It must be regarded unfair if transit via a third party's grid causes extra costs that must be covered by the customers on that grid. On the other side, it is important to take the benefits of trade into account when designing the ITC arrangement. As regards competition, the question is whether ITC affects cross-border trade in a positive or negative way.

The Regulation [7] has sparked several alternative methods to calculate the compensations to be paid and received, i.e. Marginal Participation (MP), Average Participation (AP) and IMICA. MP and AP are based on the establishment of an allocation mechanism that defines the extent to which each agent(s) located at each node uses the grid. IMICA calculates the European transmission system use caused by cross-border transfers. The methods focus on costs and load flow. The benefit impacts mentioned in the Regulation are not implemented. The procedures have been subject to much discussion and several revisions were made.

None of the negotiated methods include an attempt to include the really important benefits such as international trade, congestion rent and reduced costs associated with security of supply maintenance. An important question is whether countries with balance between generation and consumption should be rewarded and assigned transit income, compared to exporting or importing countries. The methods do not take into account the establishment of exchanges and the interactions in trade with a price response. In an efficient power system the less expensive generation resources should be used first. A compensation arrangement related to balance is not a criterion that promotes market competition, cost efficiency and utilization of the resources.

More discussion on ITC can be found in [2]. Other examples and interactions of cross-border exchange mechanisms (congestion, transit, investment, and tariffs) can be found in [4], [5] & [6]. In these cases can also be found more details on costs and benefits.

V. Conclusion

The balance between benefits and costs needs to be analyzed depending on inter-area conditions. Efficient ITC compensation mechanism still needs to be implemented among TSOs. None of the methods existing today promotes trade and competition in Europe, and the methods do not provide the right incentives towards an efficient market. The methods do not include market incentives and evaluation of benefits. Additionally, the calculations of compensation using different methods give very vague answers. In conclusion, the ITC has an incentive to limit cross-border trade and realize economic benefits leading to increased market development and increased security of supply. The result could be a less efficient market with less efficient utilization of resources.

In the paper we have shown some benefits which needs to be included when calculating ITC. They should be included in future method for ITC. Difficulty is a precise calculation of benefits due to transit, but it could be noticed that at least obvious benefits needs to be included in the calculation.

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