MRC Study on DC Losses

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Introduction

The following study elaborated by MRC Project parties aims at clarifying specific questions received from stakeholders regarding the proposed mechanism for the internalisation of losses in DC cables within the framework of Day-Ahead Market Coupling (DAMC). This mechanism had been the subject of a previous NWE study titled "Introduction of Loss Factors on Interconnector Capacities in NWE Market Coupling", presented to NRAs on April 12th 2013. The MRC Project Team refers to this latter document (in Annex) for further details on the proposal itself.

First the study elaborates on the differences between the Inter TSO Compensation mechanism (ITC) and the implementation of a DC loss factor in the DAMC, furthermore this section analysis the possible overlap between an AC loss factor and the ITC mechanism. Section 2 addresses questions linked to the coordinated implementation of a loss factor in different timeframes and addresses specific modelling issues. Next, questions raised on the impact of a DC loss factor on the flows and market coupling result are covered in section 3. A short impact assessment on possible discriminatory issues rising from the implementation of a DC loss factor in the DAMC is given in section 4.

1. Clarification on the ITC mechanism

1.1. DC-interconnector losses and the ITC mechanism

The Inter-TSO Compensation Mechanism (ITC) is a post-coupling process to compensate the use of infrastructure and losses caused by hosting transit flows. The ITC mechanism is based on more general inter-TSO agreements and is subject to more complex calculations and affects more lines. As such ITC does not cover merchant DC cables, their flow is controllable and bilateral by nature, and consequently DCs are not "directly" involved in "unscheduled" transits.[1]

Transit losses within internal and (other) cross-border networks are assigned to ITC as per Regulation EC 714/2009 Articles 13 and 14. This latter specifies in its §5 that: "*There should be no specific network charge for individual transactions for declared transits of electricity*", meaning the application of the mechanism proposed for DC in AC (where "unscheduled" transits happen) is probably unfit. All the particulars of the ITC mechanism are framed within the specific Guideline EC 838/2010. Since the integration of DC losses in the MRC aims at attributing direct losses, while the part of ITC oriented towards losses wants to compensate for losses caused by unscheduled transits, the nature of the two systems is different as such it is correct to assume that no overlap exist between both mechanisms.

[1] There is however an indirect relationship (treated below) and the prior transits cannot be considered as fully unscheduled, since they find their origin at scheduled commercial transactions; reason for the use of quotation marks in this phrase.

1.2.Impact of DC losses internalisation on AC losses and ITC mechanism

In spite of what is mentioned above, the internalisation of losses in DC cables may alter flows in surrounding AC networks, thus, also the associated level of losses in the surrounding AC network will probably change. The integration of DC losses in PCR however does not mean that the change in level of losses on the surrounding AC networks is compensated through the introduction of this DC loss factor. This is however the reason why the potential effects on flows have been considered in the Losses Study.[2] Any changes in cross border flows in AC caused by the internalisation of losses for certain DC cables would be compensated through the Inter-TSO Compensation Mechanism (ITC) –as per the method explained in the periodic ENTSOE reporting on the subject.[3]

For isolated cases in which there might be a non-negligible change in the flows at one single AC interconnector due to the introduction of a DC loss factor at a parallel (DC) route, an introduction of an AC interconnector loss factor could be envisaged.[4] However, a simplified DC network is used in the Market coupling algorithm to represent AC grids; this implies that only a linearized AC loss factor could be introduced.

The introduction of linearized AC loss factor is subject to one precondition and one consideration. The precondition would be a quantitative demonstration of the non-negligible character of the AC interconnection expected flow alteration by the affected TSOs (which is more unlikely in the case of densely meshed grids in Continental Europe). The additional consideration would be that the linearized AC loss factor would be just an exceptional instrument to bring the AC interconnection expected flows closer to their previous pattern. Given that a loss factor linearization is a much rougher approximation for AC than for DC, the AC interconnector linearized loss factor would not accurately reflect the level of losses at the concerned AC line (this is also explained in section 2.2). As such the inclusion of an AC loss factor is judged to trigger in general bigger distortions than the non-inclusion.

An additional complexity introduced by the possible inclusion of a loss factor for a particular AC line is that quantities gathered by the AC linear loss factor should be partially deducted from the ones received in ITC as a whole by the involved TSOs. This in order to avoid a double recovery of the transit part of the losses on that AC line (the main purpose of adding a loss factor would be a physical, rather than a financial one). This would also mean a review of the ITC mechanism and the introduction of a proxy in this methodology to take the above into account. Also this measure would introduce an additional error since it is only a proxy.

Therefore, the introduction of linearized loss factors in AC interconnectors needs to be studied on a case-by-case basis and the introduction of the same factor for all internal AC lines would not be desirable nor correct; since it would lead to paying twice for the same concept (once through the factor and another time through the national mechanisms for direct losses and the ITC system for unscheduled transits).

[2] This subject is treated in Section 4.3 and Appendix III Section 2 of the previous loss study.
[3] https://www.entsoe.eu/about-entso-e/market/inter-tso-compensation/Pages/default.aspx
[4] Previous Losses Study: Section 4.3.3, Page 31, last Paragraph and Section 4.4, Page 33, last Paragraph.

1.3. Conclusions on the ITC mechanism

The chapter above argues that there is no, or very limited, overlap between the ITC mechanism and the implementation of DC losses in market coupling algorithm. Both mechanisms aim to address a different set of losses resulting from cross-border trade. The implementation of DC losses, over all timeframes, compensates the direct losses generated by the operation of the interconnector, while the ITC mechanism aims to compensate transit flows. The only indirect influence of DC loss integration on the ITC mechanism would be the resulting change in flow, and losses, of the AC network near the DC interconnection.

The internalisation of AC losses in the market coupling algorithm could overlap with the ITC mechanism. The introduction of a linearized AC loss factor would result in a much rougher approximation of losses on AC interconnection then in the DC case and would not accurately reflect the level of losses at the concerned AC line. Given that the flow over an AC line is not controllable, a part of the losses generated by transit flows would still require compensation via the ITC mechanism. This could lead to a double compensation of the losses and would require a revision of the ITC mechanism.

2. Clarifications on the implementation of a DC loss factor

2.1. Coordination of loss factor in different timeframes

. Stakeholders highlight that netted (opposite) flows may lead to cost internalisations higher than effected costs; especially when considering that transactions may have occurred in different timeframes, such as long term, day ahead or intraday.

The Project Team would like to clarify the following aspects:

- when opposite flows happen in the same timeframe, losses are only applied to the netted composite flow, meaning they will never be accounted for twice, or exceed the actual cost of losses in the considered timeframe for the DC cable. This is elaborated on in section 0 and 2.1.3 for the IFA and BritNed interconnectors;
- when the opposite flows happen in different timeframes and in absence of negative prices an over-compensation of the cost of losses becomes possible. However, as elaborated on below, the actual loss cost is linked to the final physical flow.

2.1.1. Proposal for losses implementation in the XBID project

The envisaged idea for ID in the XBID project has as main characteristic that the losses are compensated by energy, i.e. the sold volumes will include the bought volumes and the losses for each border. As a consequence, the volumes at the sending and the receiving end of the interconnector are different, similarly as for DA; the loss factor being then a fixed percentage of the exchange. The difference between the planned losses and the actual losses will be on the account of involved TSOs.

If losses would be implemented in all timeframes under an identical mechanism to the one proposed in the previous Losses Study and this would be adequately coordinated for the aspects above; there is no risk for losses to be over-compensated. Each flow-losses segment would remain valuated at the market conditions of the time at which the respective transaction took place, however, adjustments would be made ex-post to the financial provisions for losses so as to avoid an overcharging.

Regarding inter-timeframe coordination and independently of netting, if the losses mechanism is implemented in DAMC but not in the Intraday (ID), conclusions in Epigraph 4.8 “Effects on Intraday Trading” (Pages 35-36) of the previous Losses Study apply.[5]

> More particularly: *[…] “if the positive effect on the losses of an ID trade in a direction decreasing the DA flow (this would decrease the losses) is not taken into account this may prevent ID transactions that would have been efficient otherwise. As a second conclusion: if a loss factor is included in DA allocation it should also be included in ID allocation to maximize the welfare gain. This is why NWE TSOs have requested the inclusion of loss factor functionality in the ID allocation mechanism" […]*

Should losses in DC cables be implemented, a coordinated deployment in all timeframes is preferable. The mechanism should in that case be similar/compatible/corrected in all timeframes in order to avoid possible market distortions between the different time horizons. The Draft Forward Capacity Allocation network code Article 35 §4[6] states that for both FTR options and PTR the losses (allocation constraints) for interconnectors should be taken into account if they have been included in the DA capacity allocation. *[…] “In case allocation constraints on interconnections between bidding zones have been included in the day-ahead capacity allocation process, they shall be taken into account in the proposal for nomination rules” […]*. Thus, coordination would also be guaranteed, in this sense.

2.1.2. Coordination of DC loss factor for the IFA interconnector

DC Losses are already integrated in all time frameworks and associated to the Deemed Metered Volume in the publically available Access Rules[7] for the IFA HVDC Interconnector between France and the UK.

> *“If a User submits a valid Mid-Channel Nomination (MCN) for an Energy Transmission <u>for a Settlement Period</u>, then the Operators will ensure that a corresponding Deemed Metered Volume, <u>adjusted for losses</u> on the Interconnector and for any reductions in MCNs as a result of Curtailment, is allocated to the relevant Energy Accounts of the User for the purposes of each*

[5] “Introduction of Loss Factors on Interconnector Capacities in NWE Market Coupling”, presented to NRAs on April 12th 2013; referred to simply as “the previous Losses Study” hereafter.

[6] FCA draft of September 30th

[7] http://clients.rte-france.com/htm/an/offre/telecharge/IFA_Acces_Rules_v9.pdf, v10 applicable from 1st July 2016 on, but with same principles

of the Balancing and Settlement Code and the RTE Settlement Arrangements using the Deemed Metered Volume allocation rules set out"[8] [...]

"For each Settlement Period, the Deemed Metered Volume of each User for a direction is equal to the maximum between 0 and the net of the Long-Term, Daily and Intraday Mid-Channel Nominations (as amended by any Curtailment) of that User for that Settlement Period integrated over the Settlement Period to give a kWh figure." [9]

"The physical flow on the Interconnector is subject to losses. The Operators will apply a Loss Factor ("LF") to calculate each User's share of the losses, and Deemed Metered Volumes in accordance with paragraph 4. The Loss Factor is symmetrical between Mid-Channel and either end of the Interconnector (Sellindge and Les Mandarins)"[10] [...]

"4. Adjustment for losses

4.1 For the purpose of the Balancing and Settlement Code, the Operators will send to the SAA[11] *(as defined in that Code) a program called BM Unit Metered Volume expressed in kWh at Sellindge in half-hourly points and calculated by this formula:*

(a) for a BM Unit in the direction from France to England:

*BMUMV = (1-LF) * DMV; and*

(b) for a BM Unit in the direction from England to France:

*BMUMV = (1+LF) * DMV.*

4.2 For the purpose of the RTE Settlement Arrangements and for an export from France to England, the Operators will send to RTE (in its capacity as Transmission System Operator) a program called "Programme d'Export à Mandarins" expressed in kWh at Les Mandarins in half-hourly points and calculated by this formula:

*PEM = (1+LF) * DMV*

4.3 For the purpose of the RTE Settlement Arrangements and for an import from England to France, the Operators will send to RTE a program called "Programme d'Import à Mandarins" expressed in kWh at Les Mandarins in half-hourly points and calculated by this formula:

*PIM = (1-LF)*DMV.*

4.4 In paragraphs 4.1, 4.2, and 4.3, "DMV" means the Deemed Metered Volume calculated for that User for that Settlement Period under paragraph 2 above."[12] [...]

[8] IFA Access Rules v9.0 (2014) Page 45; these Rules have gone live simultaneously to NWE PCR MC.
[9] IFA Access Rules v9.0 (2014) page 109
[10] IFA Access Rules v9.0 (2014) Page 109.
[11] Settlement Administration Agent.
[12] IFA Access Rules v9.0 (2014) Pages 109-110.

2.1.3. Coordination of DC loss factor for the BritNed interconnector

DC Losses are also already integrated in all timeframes and associated to the Deemed Metered Volume in the publically available Access Rules[13] for the BritNed HVDC Interconnector between The Netherlands and the UK.

"If a Participant submits a valid request for an Energy Transmission for a Settlement Period (GB or NL), then BritNed will ensure that a corresponding Deemed Metered Volume, adjusted for losses on the Interconnector and for any reductions in Mid North Sea Nominations as a result of Curtailment, is allocated (i) on the GB side to the relevant Energy Accounts of the Unit Holders for the purposes of the Balancing and Settlement Code; and (ii) to TenneT TSO on the NL side using an E-programme notification and, in the event of Curtailment, a Single Sided Transaction;"[14]

"For each Settlement Period, the Deemed Metered Volume of each Participant is equal to the net of the Medium Term, Daily and Intraday Mid North Sea Nominations (as amended by any Curtailment) of that Participant for that Settlement Period integrated over the Settlement Period to give a MWh figure in the net direction (and zero in the other) ."[15]

"The physical flow on the Interconnector is subject to losses. BritNed will apply a Loss Factor ("LF") to calculate each Participant's share of the losses and apply this to Deemed Metered Volumes in accordance with paragraph 4. The Loss Factor is symmetrical between Mid North Sea and either end of the Interconnector (Isle of Grain and Maasvlakte).[...]"[16]

"4. Adjustment for losses
4.1 For the purpose of the Balancing and Settlement Code, BritNed will send to the SAA (as defined in that Code) a program called BM Unit Metered Volume (BMUMV) expressed in MWh at Grain in half-hourly volumes and calculated by this formula:

*a) for a BM Unit in the direction from The Netherlands to GB: BMUMV = (1-(LF/2)) * DMV; and*

*b) for a BM Unit in the direction from GB to The Netherlands: BMUMV = (1+(LF/2) * DMV.*

4.2 For the purpose of the TenneT TSO Settlement Arrangements and for an export from The Netherlands to GB, BritNed will send to TenneT TSO (in its capacity as Transmission System Operator) a program called "Export Transaction at Maasvlakte" as part of the NL Energy Programme expressed in kWh at Maasvlakte in quarter hour volumes and calculated by this formula:

*ETM = 1+ (LF/2)) * DMV*

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[13] http://www.britned.com/~/media/BritNed/Files/BritNed%20Access%20Rules%2018122014.pdf?la=en
[14] BritNed Access Rules (2014) Page 27.
[15] BritNed Access Rules (2014) Page76.
[16] BritNed Access Rules (2014) Page76.

4.3 For the purpose of the TenneT TSO settlement arrangements and for an import from GB to The Netherlands, BritNed will send to Tennet TSO a program called "Import Transaction at Maasvlakte" as part of the NL Energy Programme expressed in MWh at Maasvlakte in quarter hour volumes and calculated by this formula:

*ITM = (1-(LF/2)) *DMV.*

4.4 In paragraphs 4.1, 4.2, and 4.3, "DMV" means the Deemed Metered Volume calculated for that Participant for that Settlement Period under paragraph 2 above."[17]

Therefore, the main conclusion from this Section is that there are solutions for inter-time framework coordination of the losses introduction in DC cables and that, some of them, are already operative.

2.2. Modelling choices for the implementation of a losses constraint

The physics of AC and DC interconnections are different and, therefore, so are their loss factor calculations. In terms of modelling, EUPHEMIA can deal exclusively with linearized simplified loss factors. The loss factor is a parameter implemented in the energy balancing constraint.[18]

If the loss factors for AC lines within a meshed grid were to be made a variable derived from their physical non-linear formulas, depending on optimisation variables (flows and others) dynamically; this endogenous character, plus the discrete nature of the problem and the increased tuple depth of timeframes, nodes and directions embedded within the balancing constraint serial formulation (for each of these dimensions), would risk blocking the solver. Given the present status of development in discrete non-linear Mathematics for Operations Research, a linear simplification of losses can be considered as reasonable within the frequency for which the algorithm is meant to operate and give solutions. It is also to be highlighted that EUPHEMIA uses a simplified DC network representation and that, additionally, one bidding zone is in most cases one node,[19] meaning that only aggregated interconnectors are represented for NTC and some internal critical lines (the Critical Branches) for Flow-Based. The physical flows within the meshed AC grids can (and will) differ from the commercial ones calculated by the DAMC algorithm. This is also the main reason why AC transit-induced losses are compensated via ITC and not via the algorithm itself.

For DC interconnections, the non-meshed bilateral topology and the controllable nature of the flows they sustain (closer correspondence between the commercial and the physical flows), enable a more realistic linear approximation of their losses.[20]

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[17] BritNed Access Rules (2014) Page76.
[18] This is due to design optimisation choices. These will be explained later in this Section.
[19] Save for the bidding zones that contain also virtual nodes (Denmark, United Kingdom and Norway).
[20] Though in reality actual loss levels also deviate from the linear approximation parameter depending on DC cable technology, power flows, voltage levels, etc.

[...] *"Regulators have expressed a preference for a harmonized approach to determine the loss factor. For DC cables in NWE today, different approaches exist to determine the loss factor. Basically there are three variants:*

1) *The loss factor is based on measurements*
2) *The loss factor is based on manufacturer specifications*
3) *A combination of 1) and 2)*

And within these variants different methods are applied to find the best fitting linear loss factor. For example for variant 1) the best fit at maximum flow, the best fit at most frequent flow or the best fit at average flow can be used. The development of a harmonized approach seems appropriate as the (level of the) loss factor could influence the business case of the interconnector, e.g. by the financial firmness risk profile and through other variable operating costs".[21] [...]

Therefore, TSOs will further consider this aspect when making loss factors proposals (based on a harmonized and coordinated determination process, as per NRAs preference). The determination process of the loss factor is subject to NRAs approval.

The design choice to include losses in the energy balancing constraint (i.e. consumption minus production equals import minus export for each zone time stamp and direction), its mathematical formulation and its price properties are explained within the Previous Losses Study.[22]

Another possible option could have been the inclusion of losses as an additional procurement cost within the objective function of the algorithm itself (e.g. Tariffs functionality in Euphemia), directly. Losses would have been sourced at market clearing price. It remains less clear whether this approach could be successfully implemented within the algorithm in a harmonized way for the whole Europe.

2.3. Day ahead timeframe as start for the implementation of DC losses

The implementation of loss factors only in DA can be seen as a partial optimization. But even in that case, the welfare will increase with respect to no inclusion of losses on DC interconnectors. This is shown in the Losses Study:

> *"Inclusion of a loss factor on any interconnector is welfare increasing if the exchange induces marginal welfare losses which are adequately represented through the loss factor and if the exchange does not induce to a larger extent (positive or negative) marginal welfare losses elsewhere in the system which cannot be captured by an adequate loss factor (or a combination of loss factors) within the allocation.*
>
> *For each interconnector where the total marginal costs of an exchange are mainly caused by the losses induced by the exchange, the introduction of a loss factor would be welfare increasing if external effects can be discarded. They cannot be discarded if, due to the*

[21] Previous Losses Study: Section 4.10, Page 37.
[22] Appendix II and II.1, Pages 39 to 42.

introduction of a loss factor flows are reallocated to parts of the grids with even higher losses as a result or with the need to increase redispatch costs to a level higher than the costs of the losses included in the allocation. "[23].

The Losses Study concludes the following:

"Application of the optimality condition leads to the following conclusions.

Assuming that marginal welfare loss by exchanges can be adequately reflected by loss factors on all interconnectors:

- *The total welfare always increases if the loss factor is included on a subset of interconnectors with the highest loss factors;*
- *The highest total welfare increase is obtained if loss factors are included on all interconnectors;*
- *Total welfare may decrease if an interconnector with a higher loss factor than any of the interconnectors in the subset of interconnectors that have a loss factors included is excluded from this subset;*

This applies also to AC interconnectors if the marginal welfare loss of the exchange can be linearly related to the costs of the losses incurred by the exchange. This might especially occur for AC interconnectors which are the only AC interconnection between two market areas. Whether the welfare loss by the exchange over an AC interconnector can be adequately reflected by a loss factor needs to be verified by network analysis.

These conclusions are supported by the quantitative analysis in as far as the impact of marginal welfare losses (caused by exchanges) that are excluded from the market coupling can be neglected." [24]

2.4. Implementation of losses for inland DC-Interconnectors

Elia and Amprion are currently analysing the integration of an inland DC interconnector between the Belgian and German bidding zones in the CWE FB Market Coupling. The Flow Based capacity methodology needs to be adapted to take into account the particularities of a DC cable. In particular, the concept of "advanced hybrid coupling" must be further developed in the FB methodology. DA Market Coupling is based on a global optimization of economic surplus (i.e. social welfare) in the MRC region and the future DC cable between the Elia and Amprion grids will be used to offer DA capacity between east and west inside CWE. The CWE FB methodology will compute the exchange of energy between the different hubs till a constraint is reached on a critical branch in the referenced grid. Elia and Amprion will also analyse whether it could be feasible to implement losses on this DC cable in line with the rules already in place in the market coupling process. Since this project is still in a preliminary phase, it is not yet possible to make any statements on the inclusion of losses for inland DC interconnectors in the DA MC.

[23] Previous Losses Study: Section 4.9, Page 25
[24] Previous Losses Study: Section 4.2.4, Page 28

2.5. Harmonisation of DC loss factors for implementation at pan-EU level

Regulators have already expressed their preference for a harmonized approach regarding the determination of the loss factors. But not only the determination but also the inclusion of the loss factors could be harmonized at a pan European level. The decision whether losses would be implemented on a DC interconnector could be supported by a study at pan European level. The implementation of a loss factor on an interconnector should increase the overall economic welfare. However it could be decided not to implement losses if there is an additional external impact (see Chapter 3). Also other requirements could be added to this list to assure an inclusion of the loss factor.

2.6. Conclusion

It was shown that the coordination of the losses on DC interconnectors over different timeframes exists already today and a future harmonisation of losses implementation is also being envisaged in the XBID project. Moreover, the coordination takes into account netting over different time frames and takes into account the market conditions for each respective timeframe. As was shown in the NWE losses study, introducing losses in the DA timeframe is only a partial optimization. The project team therefore suggests, that if losses are implemented on a certain DC interconnector, the implementation of these losses should be harmonised over all timeframes when possible.

At this moment losses can only be modelled as a linear loss factor in the EUPHEMIA algorithm due to its DC representation of the grid. For DC interconnectors a linear representation of losses is sufficient, however using a linear loss factor for AC cables is deemed non feasible due to the uncontrollable nature of meshed AC grids.

3. Impact assessment of DC loss factor implementation

3.1. Impact of DC loss factor implementation on AC flows

DC interconnector losses internalisation will change the flows on the DC interconnectors and, as a consequence, alter the flow pattern in their surrounding AC networks causing local variations in losses and, potentially, re-dispatch costs for these latter.

> *"The marginal costs incurred by any interconnector exchange (AC or DC) inside the AC network of the connected bidding zones could include for example increase or decrease of internal grid losses and re-dispatch costs due to internal congestions. This will depend highly on the grid topology and the distribution of load and generation over the grid as well as on the number of flow paths that enable the exchange. As grid topologies are different in different market areas, interconnections generally are meshed and the grid loading pattern changes from hour to hour, the relationship between interconnector exchanges and the marginal costs incurred inside the AC network of the interconnected bidding zones is not*

obvious. It is assumed that the correlation between an exchange and the marginal cost of the internal grid depends on the grid topology, may include other exchanges and has a more or less random character with a bias depending on the grid topology and market scenarios".[25]
[…]

In general, it can be said that highly meshed internal AC networks, combined with a relative low change in flow on the surrounding AC lines[26] tend to diminish these deviation effects. Certainly when considering a frequent price convergence environment and a harmonised European DC losses implementation scheme.

In some particular cases, the deviations may be more significant. These latter cases often involve radial networks where there is only one AC line (or a few) constituting the sole route alternative to the DC line. In these instances, the implementation of losses would imply the prioritisation of the AC route (where losses are compensated via another mechanism and have not been fully internalised in the DAMC mechanism).[27] This would bring about the consequent increase in AC congestion and its potential associated costs in re-dispatch.

Additionally (and out of the previous radial case), when the losses costs would not be covered by the DA price differential between two bidding zones linked by an DC interconnector, this may have the effect of shifting all the flow (otherwise meant to circulate through that cable) to a more losses-efficient DC interconnector (lower loss factor); reason for which an uncoordinated losses implementation (only in some DC lines or with an arbitrary and not-sufficiently audited DC loss factor) would not be recommended by the Project Team.

In words of the Previous Losses Study:

"The total flow on a border with both AC and DC interconnectors and a loss factor applied on only the DC interconnectors will reduce or remain equal. The magnitude of the change in flow will depend on the loss factors applied, the slope of the demand and supply curves, the interconnector capacities and the price differences. […]

Under certain conditions the AC interconnectors may take over flow from the DC interconnectors. This occurs when the relative remaining price differences are lower than the loss factors on the DC interconnectors and the AC interconnectors are not congested. The shift in flow (from DC to AC) may substantially influence the marginal operating costs of the impacted AC interconnectors and grid, for example by increased exchange over alternative AC interconnectors and/or losses and dispatch costs induced in the AC grid. In this case, a loss factor on the AC interconnector may also need to be considered".[28] […]

[25] Previous Losses Study: Section 2.3, Page 7.
[26] just for the amount of lost energy in one cable versus the whole internal AC transmission capacity
[27] Please see the ITC Mechanism Section of this document for an explanation on why the direct internalisation of losses on AC interconnectors in the DAMC mechanism is not recommended (contrary to our recommendations for HVDC lines).
[28] Previous Losses Study: Section 4.3, Pages 28-32.

Having all this in mind, the Previous Losses Study introduced the disclaimer that full AC welfare effects had not been measured.[29] However, the same Study also performed a more detailed flow analysis in order to determine whether the induced flow deviations at the involved AC borders and the related DA price differences caused per hub were significant under several losses introduction modalities (same loss factor in all HVDC cables, different factors, partial implementation involving only some cables, etc.[30]). Appendix AIII.2 contains the flow indicators and also a summary of the observed effects (more in terms of properties than exhaustively). Appendix A IV contains the full tables with impacts in the flows per border for each indicator and also the effects on the different net hub positions. The main conclusion is that flows change, in most cases not that much, but sometimes more importantly than others, depending on topology, market conditions and other factors.

In sum, it can be concluded that (due to the identified triggers above), flow and price deviations can and have been observed but that, in most cases, these are not significant and, thus, it is likely that advantages from the introduction of a well-coordinated pan-European system for DC losses internalisation would not be offset by these effects. For the particular cases in which this may not be the case due to topological reasons (see the next Section), alternative solutions or exemptions from the application of the losses mechanism for DC could be proposed in order to tackle this effects.

> *"In particular these effects have been observed from the simulations on the DE-DK1 and SE-FI borders. In case of DE-DK1 the increase of flows on the AC interconnector was prevented in run#2[31] because the harmonized loss factor on all DC interconnectors prevented any loss factor merit order effects on parallel routes into DE"*.[32]

For areas where the flow deviations had been perceived to be more important (Finland and Denmark during the last study and thanks to the results of the flows indicators) some separated additional studies were performed in order to evaluate the convenience of the internalisation of losses within HVDC cables (see the next Section).

Since some triggers for flow deviations also depend on the prevailing market conditions, it would be recommendable to periodically reassess the welfare efficiency of the European losses internalisation mechanism for HVDCs, so as to reconfirm that this does never cause important variations in prices or flows. In this way we would be constantly reassured that AC effects will never negatively affect the welfare gains in the HVDC part.

3.2. Particular studies for the cases in which AC flow deviation effects have been detected

3.2.1. SVENSKA KRAFTNÄT-FINGRID

SVENSKA KRAFTNÄT-FINGRID is a typical case of radial network with parallel AC-DC routes. In this case FI-SE3 is a subsea HVDC and FI-SE1 is an AC interconnection (see Figure 1). The introduction of

[29] Section 3.1.1, Page 10.
[30] Please see the run scenarios description at Section 3.1.3 (bottom), Page 11.
[31] This run was performed with equal loss factors in all the HVDC interconnectors.
[32] Previous Losses Study: Section 4.3.2, Page 30.

losses in FI-SE3 would imply a reduction of the HVDC usage and (at least theoretically) an increase of the flows in the alternative AC route. This would in turn boost AC losses, congestion and re-dispatch costs.

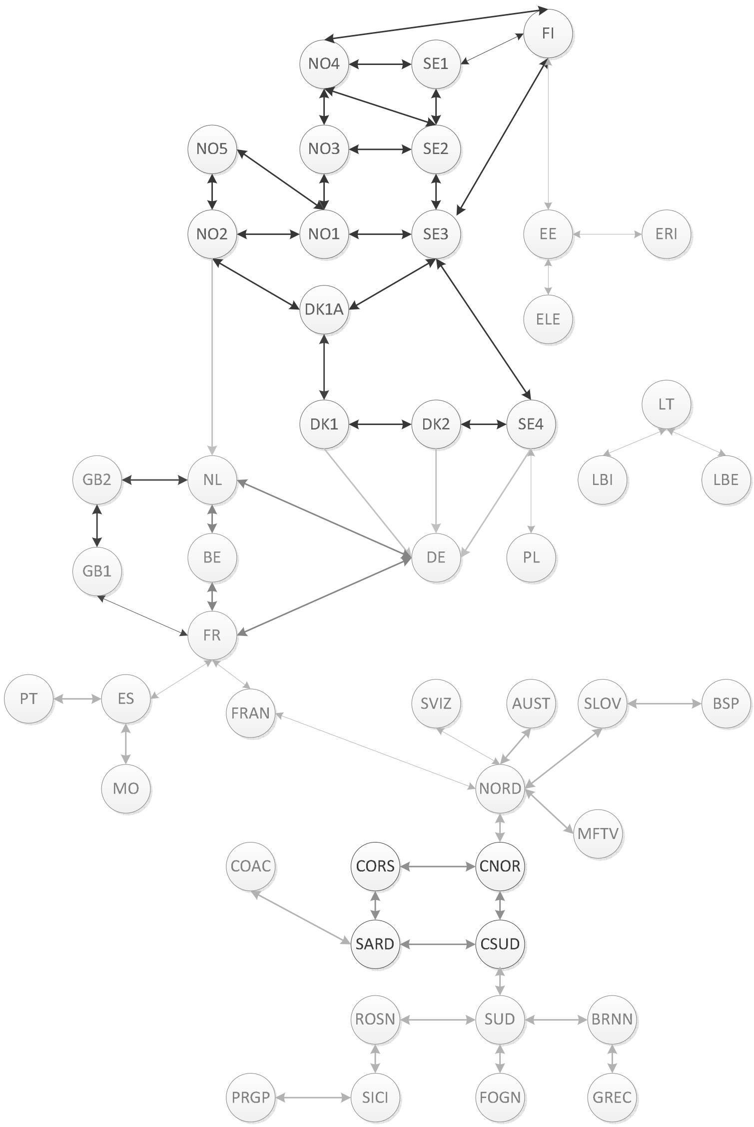

Figure 1 - PCR Topology (2013 Status)

In order to confirm the potential existence of the mentioned effects a Preliminary Study was performed by the two affected TSOs.

> Regarding the method used: *The estimation of Swedish AC-grid loss cost is based on power flow simulation with PSS/E*[33]*. In these simulations three real scenarios were used: Winter (3 January hour 08-09), Spring & Autumn (10 October hour 08-09) and Summer (16 July hour 09-10) all from 2011. Chosen scenarios are created from planning grid model, which was updated with generation, load and cross border flow information of the particular hour provided by the Operations Department. The scenarios were modified to include some new*

[33] Simulation software

interconnector flows. These flows used within the Preliminary Analysis come from the Previous Losses Study. *Two simulations were run for each of the scenarios studied. Run#1 is the base simulation and Run#3 is the simulation for which the loss factors have been introduced in DC-interconnectors.*[34]

In terms of uncertainties: *the SVENSKA* KRAFTNÄT-*FINGRID Preliminary Report simulates losses using a reduced model of the Swedish-Finnish systems. This result in a less detailed study of the power system and it will not provide correct total costs for the AC grid losses.* […] *The aim of the Preliminary Report was just to show the difference between Run#1 and Run#3*[35]*, i.e. the exact total amount of AC grid losses was of less importance at this stage*[36]*. Besides, the data from the interconnector from SE3 to NO1 (nr. 1211) was not available within the material provided by the Previous Losses Study. Therefore no changes were made on the power flows between SE3 and NO1 for any of the simulated scenarios (the power flow from the estimation of each corresponding hour was chosen). Furthermore, DC interconnectors were modelled in a simplified way and their losses were not represented but in a partial way. This means that losses in Run#3 would most likely be a little smaller relative to Run#1 if the losses on the DC-interconnectors are optimized*, as in real-life it is the case.

The grid losses annual costs are calculated from an average line load an average area price for each season for a total of 8760 hour in a year. The cost is the difference between Run#1 (no losses in DC) and #3 (with losses in DC), negative cost means an increase in the AC losses cost.

2011	Average AC-losses in FI [MWh/h]		Average FI Area Price [€/MWh]	Difference in AC-loss cost in FI [€]
Run	**Run #1**	**Run #3**	**2011**	**#1 - #3**
Winter	192,5	198,1	40,98	-670 112
Spring&Autumn	117,9	117,8	42,66	12 457
Summer	98,5	97,5	46,33	135 296

2011	Average AC-losses in SE [MWh/h]		Average SE Area Price [€/MWh]	Difference in AC-loss cost in SE [€]
Run	**Run #1**	**Run #3**	**2011**	**#1 - #3**
Winter	984,8	981,3	53,00	1 083 320
Spring&Autumn	262,0	267,0	44,90	-1 311 080
Summer	962,6	943,4	46,20	5 180 314

Figure 2 - Impact of DC Losses Introduction (Difference of Losses in AC Lines)

Figure 2 shows that by implementing a loss factor for the DC-interconnectors the Swedish grid will increase its annual costs for grid losses. But it can be discussed how the total losses in a wider area is affected. The power flow is taking different a way than through the Swedish power system, basically the power transmission losses will appear somewhere else outside the modelled SE-FI power grid.

[34] This and the next paragraphs in cursive within this Section are directly readapted from SVENSKA-FINGRID Preliminary Combined Study on DC Losses Implementation within NWE.

[35] See the run scenarios description in previous study at Section 3.1.3 (bottom), Page 11

[36] Given that this study used a simplified representation of the grid.

Therefore main results of the analysis demonstrate that:

1) As expected in theory, the introduction of a loss factor in the FENNOSKAN (FI-SE3) HVDC link alters the losses pattern in the surrounding AC networks of both Finland and Sweden
2) In order to get a correct appreciation of the order of magnitude of this effect, the whole Nordics network should be modelled, due to the realised effects on surrounding systems
3) Within the previous model, not only average DC flows should be studied, but also flow profiles including some of the extreme cases (and their occurrence rate) since the magnitude of DC flows importantly impacts results -as seen in the different seasons analysed for the study
4) Besides, induced AC network re-dispatch costs would need to be evaluated within the model
5) In general terms, the whole impact on flow patterns and network operation associated costs would need to be evaluated for these cases… In sum, the Preliminary Analysis demonstrates that a more detailed study is needed for this particular case.

Due to the restrictions in PSS/E modelling a different study should be performed to fully show the consequences of the introduction of a loss factor in the Scandinavian power system. For example, SVENSKA KRAFTNÄT is currently not using PSS/E for loss studies but another software, "SAMLAST". This program could more specifically portray the grid loss characteristics over a year and for the all the Scandinavian power systems. It should be pointed out that this kind of study would need more time to conduct.

The Detailed Regional Study mentioned above is rather complex and will be elaborated by the involved TSOs whenever there will be a decision for a coordinated EU-wide implementation of DC losses. This will serve as a means to further evaluate whether there would be some economical grounds to justify a particular FENNOSKAN exemption from the DC losses internalisation scheme.

3.2.2. STATNETT

STATNETT has conducted a study for their perimeter and that of the surrounding TSOs (in NL, DK, SE and DE). Their study confirms that the internalisation of losses in DC cables alters (as expected) the flow in DCs. These will not flow until the price differential covers the cost of losses and DC cables with lower losses factors will see their use prioritised with respect to others bearing higher losses (efficiency).

Moreover, STATNETT study demonstrates with an example that DC losses partial incorporation (in some DC cables yes and in others not) can trigger significant changes in the flows of neighbouring DCs provided some conditions are met. These conditions imply that there should be two or more alternative parallel DC routes with at least one having spare capacity and that there should be no congestion bottlenecks in the system at any of the DC landing points. STATNETT has identified two alternatives where this could be an actual problem, these are represented in Figure 3 (DC cables in red and routes represented by blue arrows). They also explain that, at present, the fact that some DC cables have losses approved and others not, is already distorting the pattern of flows at a wider European level.

Figure 3 - Potentially Problematic Routes STATNETT

One of the potential problematic routes for partial incorporation of losses involves NO2-NO1-SE3-DK1 (see Figure 1 for Topology) and the other one NO2-DK1-DE-NL. For the first one a 2010 to mid-2012 analysis shows that the "no bottlenecks" condition is complied with in around 37% of the time, whilst for the second in only 4% of the hours in the year.

The study concludes that, within the NO2-NO1-SE3-DK1 DCs perimeter, from January to June 2012, there was more than 10MW of available capacity within the DCs in about half of all the hours in which all the associated bidding zones were converged. If losses would have been considered only in SKAGERRAK (NO2-DK1 DC cable), this would have caused an average flow increase in KONTISKAN (SE3-DK1 DC link) of 92 MW. This increase would have mainly come at night. This means any losses implementation needs to be well coordinated among all DC cables in order to ensure efficiency.

In terms of the impact in AC flows of a complete DC losses incorporation, the study concludes that there is indeed also an effect (and thus an impact on AC losses), but (however) the calculations point out at the fact that this impact averages out along the year (see Figure 4 and Figure 5).

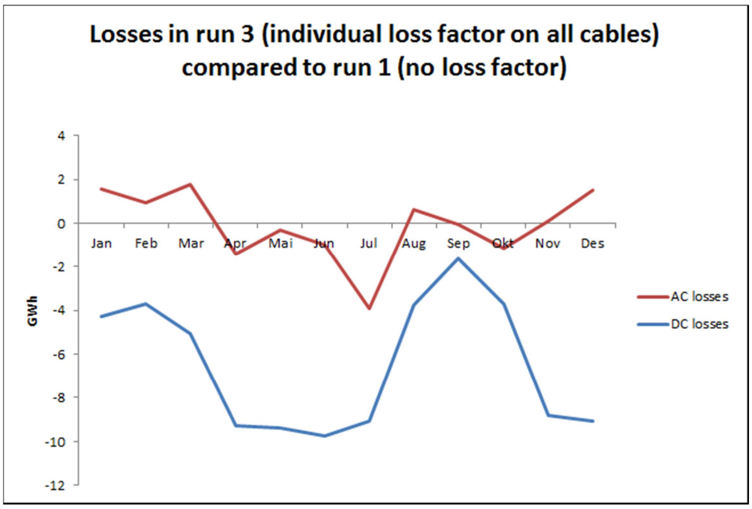

Figure 4 - AC/DC Losses Comparison STATNETT (2011)

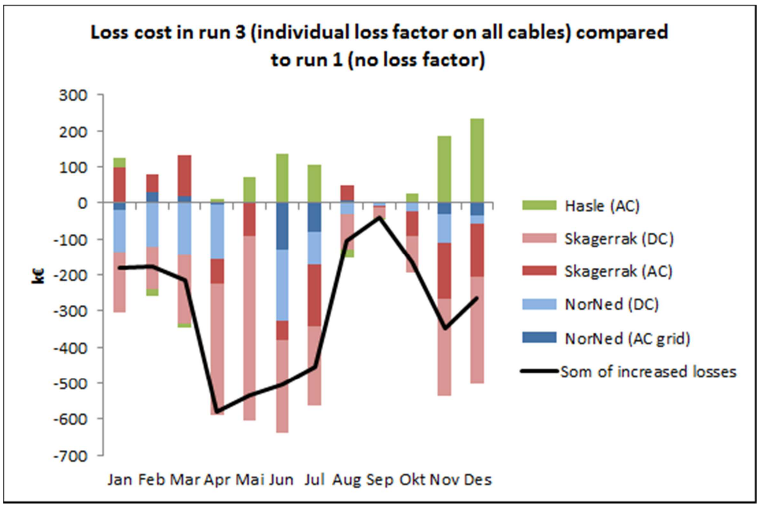

Figure 5 - Losses Split STATNETT (2011)

In sum the main messages of STATNETT is that the incorporation of losses in all DC cables would lower the losses in DC cables whilst it would keep the losses on AC unchanged

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Notwithstanding the potential exception above (FINGRID-SVENSKA), it is to be noted that the Previous Losses Study[37] did not find any other significant and systematic deviation of flows within other AC borders; meaning that (most probably) the positive effects for welfare of the internalisation of losses within HVDCs, would not be totally lost in the induced additional AC losses and re-dispatch costs.

It is to be noticed, though, that several new DC cables between the Nordics and Continental Europe and between the Nordics and the UK are currently under study or in permitting phase. Thus, all the conclusions above refer exclusively to the 2013 status-quo (existing DC cables). A periodic high-level DC losses reassessment at pan-European level would be desirable. Equally, each time that a new DC cable would be commissioned in areas where there were problems before (or perceived to be at risk by the involved NRAs/TSOs thanks to the high-level reassessment) a more detailed regional study should be made. This latter would cover the involved Capacity Calculation Regions only and would complement the high-level reassessment. In absence of any demonstrated concerns by the involved stakeholders and of any significant effects measured within the periodic pan-European check study, it could be assumed that the above conclusions would still hold and, therefore, the implementation of DC losses would be still recommended.

3.3. Impact on AC grids further away than the bordering bidding zones

The Preliminary SVENSKA KRAFTNÄT-FINGRID Study mentioned in the previous Section demonstrates the implementation of a DC loss factor could have an impact on the AC grid.

[37] "Introduction of Loss Factors on Interconnector Capacities in NWE Market Coupling", presented to NRAs on April 12th 2013.

By implementing a loss factor for the DC-interconnectors the Swedish grid will decrease its annual cost for grid losses. But the only scenario where there was some recognisable difference in grid losses was the scenario with the summer load. This was mainly due to reduced export levels on HVDC to Germany and Poland and a higher exporting to Denmark via KONTISKAN DC (DK2-DE). This meant that power would flow from Sweden through Denmark and finally to Germany and Poland. The reason why this scenario (summer) has shown a decrease in grid losses is because only the Swedish grid has been modelled. If the whole of Scandinavia were to be modelled, overall grid losses would probably be greater. The final detailed regional studies for cases in which the pan-EU high level study has detected some potential problems, must consider the different paths of the transmitted power and not only one component (DC-interconnectors), or the power system of just one country.[38]

In the flow result table of appendix IV of the Losses Study[39], the flows on each interconnector for both directions at each side of the interconnector for the hours without congestion are shown. There is almost no impact for the AC interconnectors for the implementation of losses on a subset of the interconnectors (Run#4 and #5, i.e. losses on IFA, Baltic and BritNed). If losses are implemented on all DC interconnectors, the impact on the flow on some AC interconnectors is increased; however, this is in general still limited. Thus, the Previous Losses Study at NWE level demonstrated too that the implementation of DC losses did not lead to significant AC flow deviations everywhere.[40] As a consequence, the Detailed Regional Study should only be performed when another generic high-level study, or the involved TSOs/NRAs would raise concern for the possibility of these effects to happen. On the basis of the Previous Losses Study results, we can recommend that the Detailed Regional Study should serve the purpose of granting punctual exceptions for the DC losses implementation scheme.

If the implementation of a loss factor has a significant impact on the flows of one or several AC interconnectors, additional analyses will be necessary. In some specific cases, it could be required to implement a solution in order to avoid flow on some AC interconnectors. However, one should also take into account that the AC transit losses are partially covered by the Inter TSO Compensation mechanism (ITC) and are in that way taken into account. DC cables are not taken into account in this mechanism.

In addition, TSOs perform also local measures (such as topology changes due to security of supplies reasons, maintenance ...) which have also an impact on the flows in the neighbouring grids. One could assume that the impact on the flows for a topology change is also significant.

3.4. Price formation and transparency with DC losses

If losses are introduced on a DC interconnector, the price properties on that border will slightly change between the adjacent bidding zones. The relative price difference is defined as (1- loss factor)*(price on import side).

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[38] Readapted from SVENSKA-FINGRID Preliminary Combined Study on DC Losses Implementation within NWE.
[39] Previous Losses Study: Flow Results Table (Pages 69-75).
[40] Previous Losses Study: Flow Results Table (Pages 69-75).

The Losses Study shows the following price properties:

- *"The loading factor (flow as percentage of the capacity) is 100% if the remaining relative price difference is larger than the loss factor.*
- *The loading factor is up to 100% if the remaining relative price difference is equal to the loss factor.*
- *The loading factor is 0% if the remaining relative price difference is lower than the loss factor.*

The following table shows some examples of resulting loading factors as a function of remaining relative price difference and loss factor.

Remaining relative price difference	*Loading factor at a loss factor of*				
	N/A or 0%	*1%*	*2%*	*3%*	*4%*
0,0%	*≤100%*	*0%*	*0%*	*0%*	*0%*
1,0%	*100%*	*≤100%*	*0%*	*0%*	*0%*
2,0%	*100%*	*100%*	*≤100%*	*0%*	*0%*
3,0%	*100%*	*100%*	*100%*	*≤100%*	*0%*
4,0%	*100%*	*100%*	*100%*	*100%*	*≤100%*

The N/A stands for not applying a loss factor which is the same as applying a loss factor of 0%"[41]

If losses are introduced on an interconnector or a region, it is no longer possible to have price convergence. If losses are only introduced on DC cables in neighbouring regions, the impact on the price convergence is low in the region itself. However, a limited decrease of the price convergence is observed in The Losses Study due to inclusion of a loss factor on interconnectors in neighbouring regions.

In The Losses Study, the impact on the prices is shown in the table below. The run with no losses implemented is compared with the run with an individual loss factor on all existing DC cables.

In general, this table indicates that the change in prices due to the inclusion of a loss factor stays in absolute sense during 98% of the time within a couple euros. The prices are differently impacted per bidding area. The price changes are positive or negative depending on hours.

Bidding area	min	1st percentil e	Average	stdev	99th percentil e	max
GB1/GB2	-8,49	-1,97	0,11	0,85	2,18	10,54
FR	-4,76	-1,35	0,01	0,47	1,35	3,53
BE	-4,76	-1,38	0,01	0,47	1,35	3,53
NL	-3,30	-1,68	0,07	0,66	2,01	7,14
DE	-3,81	-1,45	0,02	0,60	1,59	20,04

[41] Previous Losses Study: Section 4.1.1, Page 17.

DK1	-7,12	-2,85	0,16	1,33	3,47	20,04
DK2	-17,07	-2,25	0,28	1,34	3,66	20,79
NO1	-3,65	-1,19	0,07	0,43	1,70	4,18
NO2	-3,65	-1,32	0,08	0,47	2,01	4,18
NO3	-2,49	-1,21	0,03	0,40	1,34	3,55
NO4	-6,03	-1,21	0,03	0,39	1,30	3,55
NO5	-3,65	-1,13	0,07	0,41	1,69	4,18
SE	-4,06	-1,40	0,04	0,48	1,49	3,55
SE1	-2,55	-1,08	-0,01	0,39	1,23	3,01
SE2	-2,55	-1,08	-0,01	0,39	1,23	3,01
SE3	-4,23	-1,84	0,12	0,70	2,37	5,64
SE4	-17,07	-2,67	-0,02	1,28	2,57	7,99
FI	-11,07	-2,19	0,02	0,87	2,45	9,02
EE	-13,61	-3,89	0,74	3,19	13,84	36,20
PL	-5,48	-1,56	0,23	0,70	2,47	5,51

Table 6: Change in prices from simulations without losses and simulations with individual loss factor on all existing DC cables[42]

The conclusion that is drawn in The Losses Study is the following:
"*From this table it can be observed that the change in prices stays in absolute sense during 98% of the time within a couple of Euros. Note that all price variations are positively biased due to exclusion of all losses providing generators from the order books*."[43]

Summarizing, one could say that due to the inclusion of a loss factor, the price convergence in the region itself decrease to zero and the price convergence in the adjacent regions can slightly decrease. However, there market converged to an optimal solution, even when prices did not converge. The market clearing prices are impacted by the inclusion of a loss factor. Prices can increase or decrease with the hours. But in general, the impact on the prices remains limited. However, there are some specific hours that the impact on the hours can show a significant impact. In the case that there is parallel path for a DC and an AC cable on the same border, price convergence on that border can still exists.

3.5. Incentive for DC interconnectors operators to minimize losses

The harmonized determination of the loss factor will be subjected to NRA approval. From a technical point of view, a loss factor will not be a fixed constant value. However, from a pragmatically point of view and for the implementation in the market coupling algorithm, the determination of the loss factor will give a fixed loss factor, this was already discussed in previous sections. This fixed loss factor will probably be not sufficient to cover all the losses in real time. The error on loss estimation, the part that is over or under compensated by the loss factor, will be the responsibility of the TSOs. A loss consolidation over different timeframes is done for merchant interconnectors (sections 0 and 2.1.3). Given that there is a physical settlement of losses over all timeframes, the cable operator has an incentive to represent the losses over the DC connectors as accurately as possible.

[42] Previous Losses Study: Section 4.1.3 Page 22.
[43] Previous Losses Study: Section 4.1.1, Page 22

3.6. Conclusion

Applying a DC loss factor can have an impact on the neighbouring AC grid, in general it can be said that in highly meshed AC networks the impact on flows and price differences is limited. It is likely that advantages from the introduction of a well-coordinated pan-European system for DC losses internalisation would not be offset by these effects For some specific cases, e.g. involving radial networks, the impact can be more significant. Such situations would require alternative solutions.

By the definition, the inclusion of a DC loss factor results in slight price differences between markets for the cases there is a flow over the DC interconnector even if the markets are converging. In cases price differences between markets are below the costs of the losses, there is no flow over the DC interconnector where DC loss factor is applied. In general the impact on prices remains limited.

4. Discriminatory issues related to the inclusion of a loss factor on DC-Interconnectors

4.1. Discriminatory issues with regards to other lines in the same timeframe (DA)

4.1.1. Framework

The only interconnectors currently applying losses in the MRC market coupling mechanism are IFA, BritNed, Baltic Cable and NorNed, the three first are (partially for IFA) merchant which are not part of the regulated asset base of a regulated TSO and are the result of a private investment. For DC interconnectors the losses incurred can be directly attributed to exchanges over the interconnector, and it thus welfare maximizing that the procurement of these losses takes place in the MC algorithm (Losses Study p. 25, 4.2.1).

> *"For each interconnector where the total marginal costs of an exchange are mainly caused by the losses induced by the exchange, the introduction of a loss factor would be welfare increasing if external effects can be discarded. They cannot be discarded if, due to the introduction of a loss factor flows are reallocated to parts of the grids with even higher losses as a result or with the need to increase redispatch costs to a level higher than the costs of the losses included in the allocation."*

Non-merchant, (DC) interconnectors are part of the regulated asset base of TSOs. According to article 11.6 of 2003/54/EC TSO's are required to procure the losses incurred on their assets. Often, the procurement costs are socialized via various systems.

> *"Transmission system operators shall procure the energy they use to cover energy losses and reserve capacity in their system according to transparent, non-discriminatory and market-based procedures, whenever they have this function."*

For example, the losses on the Swedish and Nordic transmission systems are covered by tariffs. While a number of DC interconnectors are part of the regulated asset base, such as (Konti-Skan, Fenno-Skan, SwePol, etc.).

The report additionally notes that (Losses Study p. 32, 4.4):

> *"If exchanges on AC interconnectors – just as on DC interconnectors - clearly induce marginal welfare losses due to the operation of the AC interconnector itself (e.g. the losses only on the AC interconnectors) then there is a comparable economic effect on the welfare induced by exchange over AC interconnectors and DC interconnectors. The welfare loss due to losses over the interconnector is then not an economic argument to discriminate on inclusion of loss factors between AC and DC interconnectors."*

4.1.2. Assessment

Before addressing the discriminatory issues, it is important to note that introduction of a loss factor on an interconnection between two bidding zones may introduce a merit order effect. This re-routing effect may decrease the flows over the interconnector applying a loss factor.

"If the question is generalized to two parallel routes into a bidding zone with on one route an interconnector on the bidding zone border with a loss factor included and on the other route an interconnector on the bidding zone border without a loss factor included then a loss factor merit order effect occurs. The route with the lowest total loss factor takes over some flow from the route with a higher total loss factor (re-routing effect). This effect is countered if the total loss factor on both routes is equalized."

In order to properly assess whether the application of a loss factor is discriminatory four distinct cases were analysed.

1. Application of loss factor on certain DC-IC discriminatory with respect to other DC-IC.

As indicated in the previous paragraph, a DC-IC should apply a loss factor representing the marginal welfare loss if the loss can clearly be attributed to the exchanges of the interconnector. We can thus consider it discriminatory to apply a loss factor on certain DC interconnector and not on others, except if it can be proven that the application of a loss factor would result in a marginal welfare loss linked to the operation of said interconnector.

When we consider two biddings zones connected via two DC interconnectors, then the existence of the re-routing effect could be an additional argument to apply a loss factor on both routes, depending on the value of the loss factor.

2. Application of loss factor on certain DC-IC discriminatory with respect to other AC-IC.

The report already indicated that a loss factor should be applied in situations where marginal welfare losses can be directly attributed to the exchanges over an AC interconnector. We can consider two types, an AC interconnector under the FBMC mechanism and an AC interconnector under the ATC mechanism.

Generally speaking, the losses on an AC line are only partly dependant on the commercial flows (allocated in the DAMC) over said line. A linear loss factor, if feasible, for an AC line would thus result in a misrepresentation of the actual marginal welfare losses induced due to exchanges over the AC line in most cases, see section 1.2.

At this moment there are no internal DC interconnections within the CWE zone. Should this be the case, then the DC line could be considered as an internal ATC border instead of a flow based constraint[44]. The treatment of an internal (within the flow based zone) DC interconnector in the algorithm will thus be different than for an AC interconnector, making it difficult assessing whether application of a loss factor on a DC interconnector is discriminatory with respect to AC interconnectors within the Flow based region.

Should a loss factor be applied on all AC-interconnectors, then we risk that only the loss factors of the constraining branches are included in the market coupling (due to the pre-solve step). The technical feasibility of this implementation needs to be analysed.

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[44] This is the case under the current Flow Based methodology, this will change in the future after the introduction of Advanced Hybrid Coupling.

When an ATC border consists solely of AC interconnectors, a general loss factor could be applied in the market coupling algorithm. However, this loss factor would be a linear approach of the total losses on the border and would only be pertinent when it accurately represents the losses introduced by exchanges of the border and if the loss factor is non-negligible.

The application of a loss factor on certain DC interconnectors can thus only be considered discriminatory with respect to other AC interconnectors when:

- The introduction of a loss factor on an AC interconnector is feasible; and
- the loss factor correctly represents the marginal welfare losses due to exchanges over the AC interconnector.

3. Other lines in the algorithm

The other lines remaining in the algorithm are the internal lines which are part of the FBMC algorithm in the CWE zone. An identical reasoning can be applied as for AC interconnectors in the FBMC algorithm

4. All AC and DC lines

The previous paragraphs cover all AC and DC lines taken into account in the MRC market coupling.

4.2. Discriminatory issues with regards to other timeframes

Section 2.1.1 showed that coordination between the different timeframes is needed when losses are applied in the DA market coupling. More specifically, we showed that the new network code on Forward Capacity Allocation requires that for both FTR options and PTR the losses (allocation constraints) for interconnectors should be taken into account if they have been included in the DA capacity allocation. In addition, sections 0 and 2.1.3 summarize the relevant paragraphs of the Access Rules of IFA and BritNed. In these rules is indicated that the final physical flow is subjected to losses, meaning that losses are applied on all timeframes (including balancing). Therefore, if losses were to be applied then, they would automatically be applied on all other timeframes when considering merchant interconnectors.

As demonstrated in The Losses Study, the introduction of losses on DC interconnectors will only have a limited impact on the day-ahead market prices. The prices of long term products (i.e. PTRs, FTRs and CfDs) are linked to the forecasted market prices. Therefore, the impact on the prices of the long term products will also be limited.

The Losses Study further states the following with respect to FTRs and PTRs:

> *"For PTRs and FTRs there is a second aspect related to the introduction of a loss factor. As prices will no longer fully converge the expected prices of these products could slightly increase. On the other hand, the issuing party (generally a TSO) of the PTR/FTR has a slightly increased financial risk: he would always have to pay out the remaining relative price difference if the definition of the long-term products remained unchanged.*

Depending on the long term product, introduction of a loss factor could therefore require a different implementation. As a general principle[45]:

- *For PTRs: the nomination right needs to be redefined taking the loss factor into account: the option to nominate includes an obligation to nominate on import and export side in such a way that the difference is always equal to the losses incurred*
- *For unused PTRs and for FTRs: the right to collect the price difference between the markets concerned has to be defined in such a way that the costs of the losses incurred are not paid out to avoid a welfare transfer between the TSOs on one hand (e.g. the consumers through the tariffs) and the PTR/FTR holder on the other hand. This welfare transfer would be equal to the costs of the losses. Alternatively a minimum price is introduced in the auctioning of these products to cater for the fact that there are market results possible with no flow (and thus no congestion income) but a remaining price difference*

There are however many implementation aspects which go beyond the scope of this analysis which would need to be studied further. In first glance, the price for the PTRs and FTRs should rise slightly for interconnectors where a loss factor is introduced as there will generally be a relative remaining price difference to be paid out (adverse flows and coincidental situations excepted). This increased price could compensate to some extent for the higher financial risk incurred.[46]"

Next, the Losses Study argues that even if no losses were to be applied in the intraday timeframe, the total welfare gain would not be negative. Suppose that on a border there is at least one interconnector with a loss factor in day-ahead allocation, this could result in a price difference between the adjacent bidding zones, but no congestion. Since the capacity is not fully used, the remaining capacity in the direction of the day-ahead allocated flow will be used in intra-day trading to annul the price difference. The intra-day trade can reduce the extra welfare that the introduction of losses could have created, but the reduction could never be larger than the extra welfare. If losses are included for the day-ahead allocation, they should also be included in the intra-day allocation in order to maximize the welfare.

4.3. Conclusion

The study concludes that it may be discriminatory to apply losses on certain DC cables alone, more precisely in cases where the application of said loss factor could create a merit order effect with other DC interconnectors. For AC interconnections the application of a loss factor on certain DC

[45] These principles are already applied today on interconnectors where losses are included in an explicit allocation

[46] Previous Losses Study: Section 4.9, Page 36.

cables can only be considered discriminatory when the introduction of AC losses is feasible and the loss factor accurately represent the marginal welfare losses over the interconnector.