Til Sekretariatet for Forsyningstilsynet

ENERGINET
Elsystemansvar

Energinet
Tonne Kjærsvej 65
DK-7000 Fredericia

+45 70 10 22 44
info@energinet.dk
CVR-nr. 39 31 49 59

Dato:
30. juni 2020

Methodology Application implicit grid loss

METHODOLOGY APPLICATION IMPLICIT GRID LOSS ON THE GREAT BELT POWER LINK

The enclosed document contains Energinet's application to introduce implicit loss handling on the Great Belt Power Link (between the bidding zones Western Denmark DK1 and Eastern Denmark DK2), in the forward, day-ahead and intraday markets as well as the rationale behind the application. This document includes a description of the applied for method and an assessment of the expected socio-economic consequences, including distribution effects, of introducing implicit loss handling on the Great Belt Power Link. Moreover, the attached appendices include additional background information relevant to the application.

The implicit loss factor is a correction mechanism for negative external effects, incentivising the market to respect the cost of electricity losses on HVDC interconnections in the market coupling.

The implicit loss handling functionality will be implemented by the introduction of a fixed annual loss factor for the Great Belt Power Link. It will be possible to adjust the loss factor based on historic median flows for all hours with flow for the interconnector during periods where capacities have not yet been provided for long-term transmission rights.

The socio-economic gain over a 40-year period from introducing implicit loss handling for the Great Belt Power Link is estimated at approximately DKK 75.39 million for Denmark.

The relevant legal basis in Denmark for the introduction of implicit loss handling on the Great Belt Power Link is the CCR Nordic Capacity Calculation Methodology article 6. 1(c). Thus, the application is based on Annex I of Regulation 943/2019, as directly applicable EU law, i.e. regulation 714/2009 and/or the European Commission's regulations on network guidelines, the CACM Regulation etc., replace any national Danish provisions on the actual subject matter, the introduction of methodologies etc. on cross-border interconnectors.

Similarly, the Danish Utility Regulator, the national regulating authority of Denmark, has the authority to issue administrative decisions based legally on directly applicable EU law. See section 1, subsection 2, no. 4, in Act No. 690 of 8 June 2018 on the Danish Utility Regulator.

Table of contents

Application

Energinet hereby applies for methodology approval of implicit grid loss handling on the Great Belt Power Link from the Danish Utility Regulator.

The implicit loss factor is a correction mechanism for negative external effects, incentivising the market to respect the cost of electricity losses on HVDC interconnections in the market coupling.

The implicit loss handling functionality will be implemented by the introduction of a fixed loss factor for the Great Belt Power Link. The loss factor can be adjusted annually based on historic median flows for all hours with flow on the connection, for future periods, where capacities have not yet been provided for long-term transmission rights.

The socio-economic gain over a 40-year period from introducing implicit loss handling for the Great Belt Power Link is estimated at approximately DKK 75.39 million for Denmark.

The relevant legal basis in Denmark for the introduction of implicit loss handling on the Great Belt Power Link is the CCR Nordic Capacity Calculation Methodology article 6. 1(c). Thus, the application is based on Annex I of Regulation 943/2019, as directly applicable EU law, i.e. regulation 714/2009 and/or the European Commission's regulations on network guidelines, the CACM Regulation, FCA regulation etc., replace any national Danish provisions on the actual subject matter, the introduction of methodologies etc. on cross-border interconnectors.

Rationale behind the application

When power flows in an electrical network, some of the energy will be lost on heating the electrical components, and the volume of power that reaches end users will thus be less than the volume generated. On HVDC interconnectors between Denmark and other countries, this loss is between one and five per cent. However, this energy loss, which constitutes a significant socio-economic cost, is not automatically included in electricity pricing in the power market. Without TSO intervention, agreed generation and consumption (after market clearance) will therefore result in a balanced market, but not an operationally balanced system.

Operational imbalances caused by losses on the Great Belt Power Link are currently handled by Energinet. Energinet uses loss forecasts to purchase power in the day-ahead market to cover any transmission losses to ensure that the system is balanced both market-wise and operationally. However, this type of explicit loss handling, which is used for losses both in the AC grid and on HVDC interconnectors, is not considered a socio-economically effective way of handling losses.

When TSOs purchase electricity to cover any loss, this affects the power price but it is not linked to the transmission interconnector(s) where losses occur. This means that market participants are not provided with the price signals necessary to consider their influence on the electrical loss.

Electrical losses thus represent negative externalities that result in an occasionally unfeasible socio-economic loss. This can be directly observed when power is sometimes traded between bidding zones at times when the value of the power trade (the price difference) is less than the cost of transmission losses. Therefore, a socio-economic gain can be achieved by considering (internalising) electrical losses in the market price.

In the AC grid, electrical losses are partially internalised in the grid tariff where a loss component ensures that participants pay a tariff according to bidding zone and time of day that reflects electrical losses. On HVDC interconnectors, losses can be internalised using implicit loss handling. Figure 1 illustrates the current situation for Danish interconnectors.

*Figure 1 Loss handling on Danish interconnectors, and progress on implementing implicit grid loss, if relevant.*Skagerrak has the methodology approved and will have implicit grid loss implemented by November 2020.*

Method for implicit grid loss handling

With implicit grid loss handling, electrical losses are represented in the market by a new limitation in the market coupling. This ensures that exported volumes are reduced by a loss factor between exporting and importing bidding zones. Thus, market prices will be affected by the new restriction as follows:

with congestion: export price < (1 - loss factor) * import price
without congestion: export price ≤ (1 – loss factor) * import price

This change will ensure that power is not traded on an interconnector unless the value of the trade is greater than the cost of the loss.

The day-ahead market algorithm already has a function for taking losses into account. In practice, implementing implicit loss handling on the Great Belt Power Link will mean that the current loss factor on this interconnection will change from nil to a positive loss factor.

Method for calculating loss factor for the Great Belt Power Link

The total quantity transferred will affect the physical losses on the Great Belt Power Link. However, the market algorithm does not accept non-linear losses, meaning that physical losses must be represented in the market algorithm by a linear loss factor. This is estimated based on the following linear description of loss:

loss = no-load loss + (loss factor * |flow|)

The so-called no-load loss is the loss seen even when there is no flow on the connection. The reason for this loss is that the cables are energised even when there is no flow in them. However, the no-load loss is very small, and we will therefore implicitly include this element in the loss factor estimate by setting the value at nil. The relationship between the linear description of losses and the actual losses is illustrated in Figure 2.

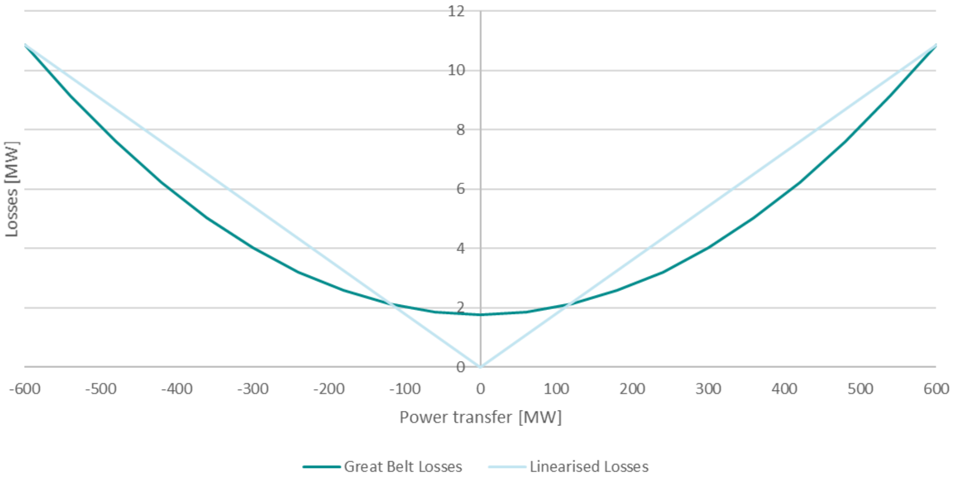


Figure 2 Great Belt Power Link losses with a given power transfer, and linearised losses.

Loss is a function of flow, and therefore, the loss factor is also an input to market clearance where flow is determined. However, due to the linear nature of the applied loss factor, a reference flow used to estimate the loss factor must be set before we know the correct flow. In this context, an obvious question is whether the loss factor should vary by the hour, day, week or season over a year. Energinet and Statnett made an applicable analysis when preparing for the approved methodology for implicit grid loss on Skagerrak in December 2019 (See Annex II), which indicated that such periodisation will only affect calculation of the loss factor to a very small extent. Therefore, the method applied on the Great Belt Power Link also uses a fixed so-called annual loss factor with possibility of annual adjustments. However, the methodology will also consider the need for adjustment throughout the year if required by circumstances. As the Great Belt Power Link also provides options of long-term transmission rights, the loss factor is updated solely for periods where capacities have not yet been provided for long-term transmission rights.

Energinet will notify the Danish Utility Regulator one month prior to any loss factor update. Energinet will inform market participants of any change at least two weeks prior to the implementation date.

The reference flow is calculated as the annual median flow for all hours with positive flow. This decision is based on the above-mentioned Skagerrak Methodology that resulted from an analysis which assessed two different averages and two different median values. The analysis did not yield significant differences in resulting loss factors (see Annex II).

When using a top-down model to calculate the loss factor, a statistical analysis of time series for measurement data (flow and loss) is used in the calculation as opposed to a bottom-up model (Annex II contains a detailed description of the two different models).

Energinet has decided to use the top-down model when estimating the loss factor for the Great Belt Power Link. Based on the above description that uses data from 2019, the reference flow for the Great Belt Power Link is 257.1 MW and results in a loss factor of 1.3 per cent. This calculation may be updated before implementation on the Great Belt Power Link and will, if updated, be based on the method described above.

Procurement of remaining grid loss

As stated in the chapter *Method for calculating loss factor for the Great Belt Power Link*, the loss factor is represented in the market coupling algorithm as a constant value. However, in the actual operation of the link, the loss factor will not be constant and it will not cover all losses, depending on the specific flow on the link.

The error of either over- or underestimating grid loss on a given interconnector is the responsibility of the relevant TSO and will be handled in the balancing market.

Figure 3 illustrates remaining grid loss, which is below the realised grid loss for a loss factor at 1,3%. Annex VI indicates that a minor shift to a loss factor of 1,5% will lead to both over and underestimation of losses different at flow different than the reference flow.

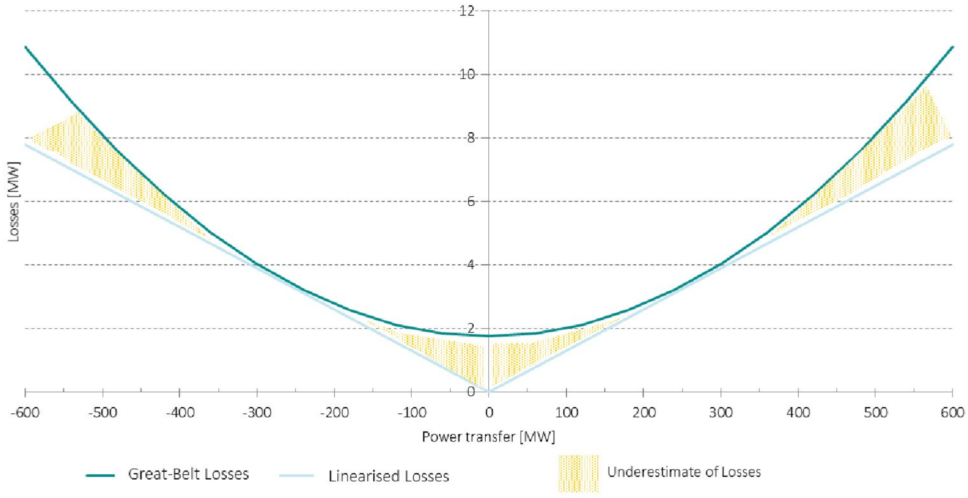


Figure 3 Remaining grid loss illustrated with the area between actual grid losses (dark blue curve) and loss factor of 1.3% in the market coupling algorithm (dashed blue line) for the Great Belt Power Link.

Consequence analysis

The implementation of implicit grid loss influences AC grid losses, the inter-TSO compensation mechanism and electricity prices in the market, which will be further discussed in this section.

AC grid

Losses in the AC grid are more complicated to describe in contrast to HVDC interconnectors where losses can be approximated with a linearisation. AC grid flows cannot be controlled in the same way as HVDC interconnector flows, and therefore, exchange and losses cannot be accurately approximated linearly.

As the market coupling algorithm can only incorporate simplified linear loss factors, we cannot include AC grid loss factors.

Thus, when implicit grid loss handling is applied to an HVDC interconnector and not the AC grid, this essentially results in elevated costs of flowing electricity through the former than through the latter, and more flow will be redirected to the AC grid. The cost of HVDC interconnector losses will decrease, whereas AC grid loss costs will increase. These external effects are also considered in the socio-economic benefit analysis from the BID analysis on external borders. These changes in costs will depend on grid structure, distribution of consumption and generation, and capacity provided to the market.

The section below provides more details on the resulting change in flow on Danish interconnectors due to the implementation of implicit grid loss on the Great Belt Power Link. One significant finding is that there are not significant changes to flows on the borders between Eastern Denmark, Sweden and Western Denmark, and Eastern Denmark, Germany and Western Denmark.

Inter-TSO compensation mechanism (ITC)

The purpose of the inter-TSO compensation mechanism is to compensate for grid loss costs in the AC grid resulting from transit flows, while the purpose of implicit grid loss is to integrate the cost of losses directly into the market coupling algorithm, thus internalising the external cost of losses. In conclusion, these systems address loss costs differently, and it is safe to assume that there is no overlap, double accounting, between these two mechanisms, as described in the MRC study, see Annex III.

ITC consist of two accounts; one for loss costs compensation and the other for providing the availability of infrastructure for cross-border flows. Further details can be found on ACER.europa.eu[1].

It is important to notice that the amount of ITC compensation can change because implicit grid loss handling changes flow patterns in the system. However, as ITC compensation is a zero-sum game, where compensation equals estimated loss costs, this merely implies a redistribution.

Flow-based

Energinet is aware that the analyses and arguments that underpin the implementation of implicit grid loss use analyses and arguments based on the NTC capacity calculation methodology.

The non-intuitive flows that occurred in the simulations are not caused by ramping restrictions, extraordinary constraints on the surrounding interconnectors, or negative prices in the exporting bidding zone, but on the market coupling algorithm that maximises social welfare (Euphemia). Consequently, if Euphemia's design conforms to the theoretical base of flow-based, including non-intuitive flows, then the socio-economic benefits of flow-based are secured.

Socio-economic consequences of implicit loss handling on the Great Belt Power Link

The socio-economic benefit of the implicit grid loss handling methodology has been analysed thoroughly in the BID3 simulation model. Here, various scenarios for implicit grid loss handling were analysed, as Energinet still aims to implement implicit grid loss handling on all Danish HVDC interconnectors.

However, as this methodology approval concerns the implementation of implicit grid loss on the Great Belt Power Link, we will only present the results related to this particular scenario, keeping in mind that the socio- economic benefits will only improve as more interconnectors implement the method.

1 https://www.acer.europa.eu/Official_documents/Acts_of_the_Agency/Publication/ITC%20Monitoring%20Report%202019.pdf provides an overview of the consequences of ITC.

Scenario calculations use a 40-year investment period, starting from 2020, and values are the net present value (NPV) effects of the scenario in 2020 in DKK million for the 40-year period.

The base case in the BID3 model is that implicit grid loss is already implemented on the Skagerrak interconnector, which is used as the reference scenario in the following. The Skagerrak interconnector is expected to have implicit grid loss implemented by the end of 2020, explaining why this is included as the base case/ reference scenario.

Reference scenario: implicit grid loss Skagerrak (loss factor equals 2.4%)

Thus, the scenario for the NPV effect is the implementation on the Great Belt Power Link as well, meaning that two Danish HVDC interconnectors have implemented the implicit grid loss methodology.

Scenario implicit: Implicit grid loss Skagerrak (2.4%) and implicit grid loss Great Belt (loss factor 1.5%).

In both the reference scenario and the scenario with implicit grid loss on the Great Belt Power Link, all other interconnectors continue to use explicit grid loss handling, except Viking Link, where implicit grid loss handling is expected to be implemented when the interconnector is put into operation.

Socio-economic welfare effect

As previously mentioned, the total socio-economic result consists of two parts: changes in market gain and changes in loss costs. The effects of implicit grid loss on the Great Belt Power Link are provided in Figure 4 below.

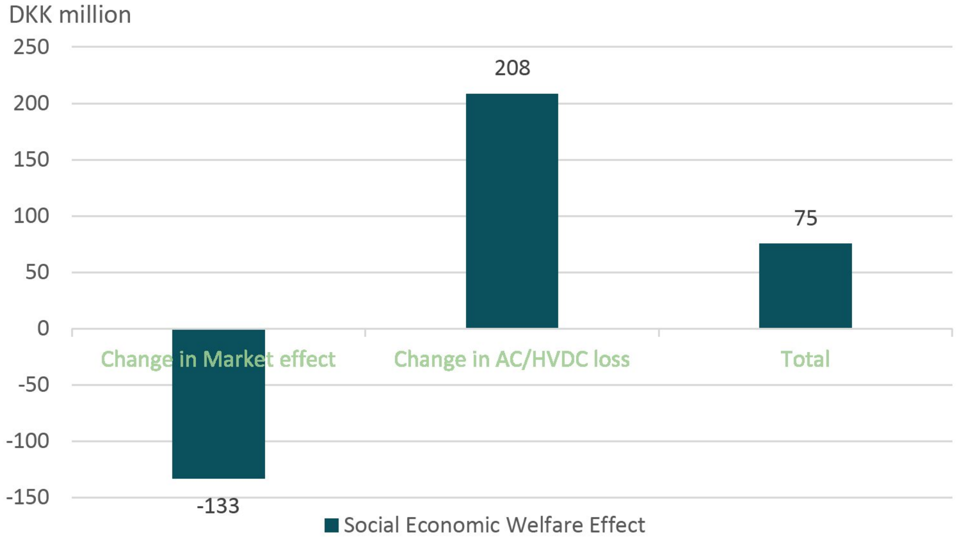


Figure 4 Socio-economic welfare effect (2020 NPV effect in DKK million) of implementing implicit grid loss on the Great Belt Power Link over a 40-year investment period.

As expected, the market gain is negative (negative socio-economic effect) significantly cause by decreasing congestion income, while loss costs decrease (positive socio-economic effect), resulting in an overall positive social-economic effect of the implementation of implicit grid loss on the Great Belt Power Link.

These effects are also illustrated in the following Table 1:

Effect in DKK million	Consumer surplus	Producer surplus	Congestion income	Benefit of decreasing DC losses	Benefit of decreasing AC losses	Total economic surplus effect
Implementing implicit grid loss on Great Belt	15.04	14.95	-163.06	202.83	5.64	75.39

Table 2 BID results of the socio-economic welfare effect analysis (2020 NPV effect in DKK million) of implementing implicit grid loss on the Great Belt Power Link over a 40-year investment period.

Of course, it could be argued that the total economic surplus stated above is not a large effect over a 40-year period. However, when it comes to improving the efficiency of markets, it is a necessary step in obtaining societal benefits. In the following section, the market effects *congestion income* and *loss costs* are described in more detail.

Market effects

The market effects of implementing implicit loss handling on the Great Belt Power Link are shown in Figure 5 with the NPV effects for Denmark in DKK million. As mentioned previously, the overall market gain for Denmark is negative. This is mostly due to the significant decrease in congestion income at DKK 161 million. Both consumer and producer surpluses experience positive effects of approximately DKK 15 million each.

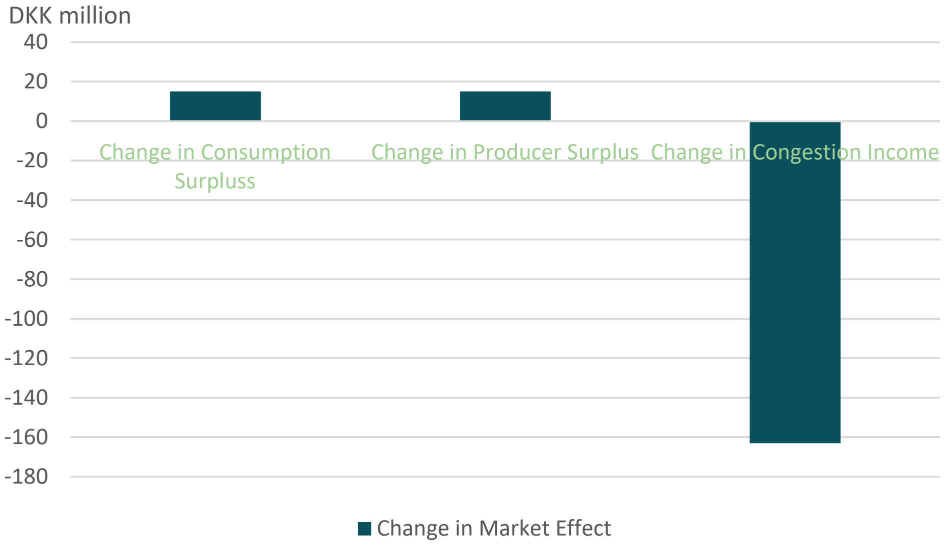


Figure 5 Market effect (2020 NPV effect in DKK million) of implementing implicit grid loss on the Great Belt Power Link over a 40-year investment period.

The distribution is a result of the price effects in question during the analysis period, where high transport costs will typically benefit consumers on the export side and producers on the import side of a bottleneck. Distribution effects between consumers and producers will thus vary over the years, with the predominant flow direction largely determining the distribution.

Tariff effects should also be kept in mind. When a TSO introduces implicit loss handling, it will no longer pay for losses using market mechanisms (purchase of losses). This will benefit tariff customers by reducing consumption tariffs. This will, in turn, compensate for any reduction in the consumer surplus to a greater extent than for the producer surplus. However, the latter element has not been analysed, and it is therefore not possible to determine the strength of the tariff effect.

The significant change in congestion income, Figure 5, is mostly due to the decreased flow on the Great Belt Power Link by DKK 135 million, which is not shown in Figure 6, as it would distort other effects too much. However, it also appears from Figure 6 that the DK2-SE4 cross section experiences a large negative effect of DKK 61 million. This can partly be explained by changes in flow, but also by pricing convergence, which decreases congestion income per MWh flow.

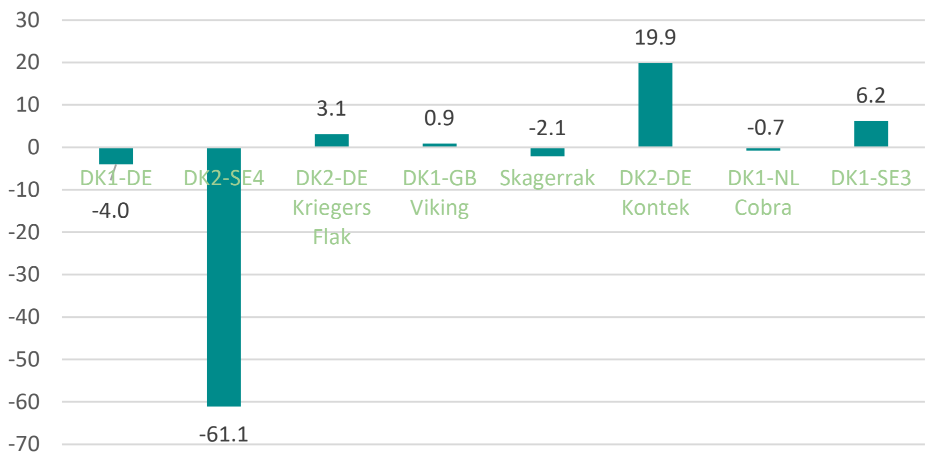


Figure 6 Danish interconnectors and NPV effect on congestion income in DKK million.

Effects on flow and grid losses

Loss costs are made up of changes in loss in the AC grid and on HVDC connections. As mentioned earlier, the cost of transmission in the AC grid and on HVDC interconnectors is somewhat reduced when implicit loss handling is introduced on an HVDC connection. Therefore, elevated transmission losses and loss costs in the AC grid and on HVDC interconnectors is to be expected. On the other hand, the total loss on HVDC connections, including the Great Belt Power Link, is expected to be reduced. The overall changes in loss costs in the AC grid and on HVDC interconnectors that have resulted from our analyses are shown in Figure 7. Total loss costs on the Danish HVDC interconnectors are substantially reduced, mostly due to the DKK 226 million positive effect on the Great Belt Power Link, while we only see a slight increase in the loss costs in the AC grids.

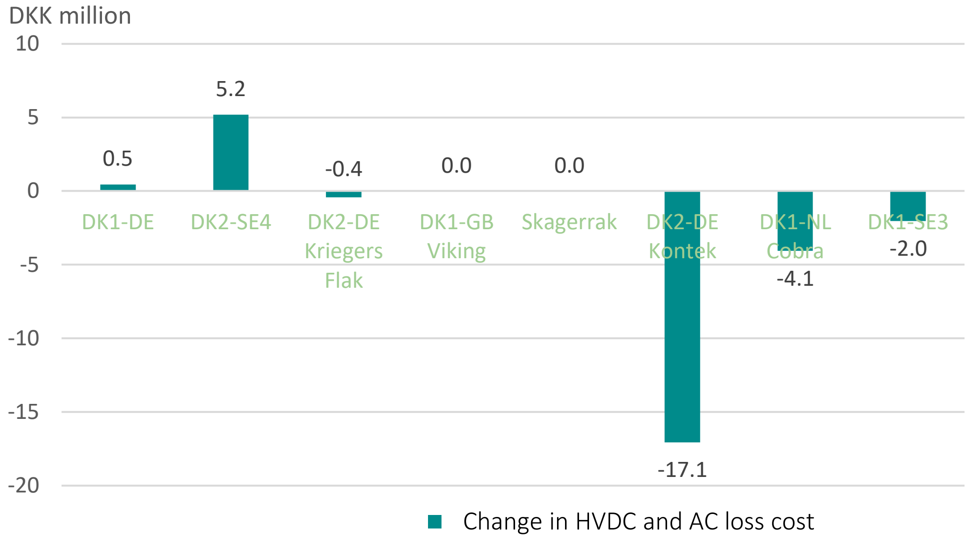


Figure 7 NPV effect in DKK million of changes in HVDC and AC loss costs (positive equals a decrease in loss costs and negative equals an increase in loss costs).

Change of flow on Danish connections

The below table indicates the yearly absolute flows of both the reference case, with implicit grid loss solely on Skagerrak, and in the scenario with implicit grid loss on the Great Belt Power Link as well. It also indicates the change in flow between these, both in MWh and percentages.

The table was created based on the methodology approval document by the Danish Utility Regulator, which utilises the same format.

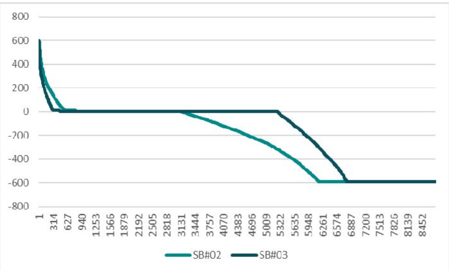
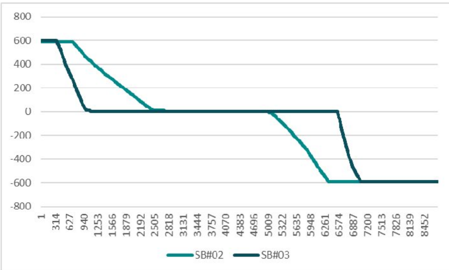
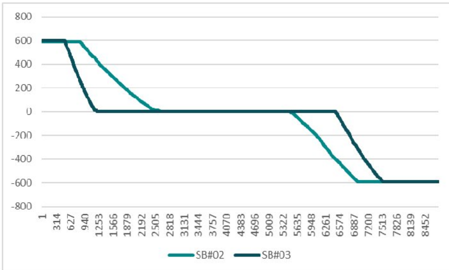
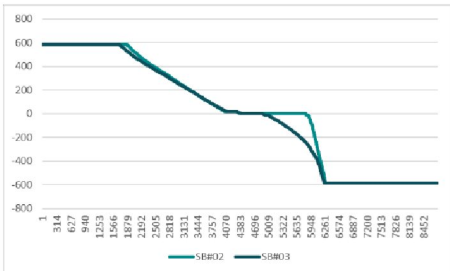
Year	(in MWh)	DK1-SE3	DK1-NO2	DK1-NL	DK1-DE	DK2-SE4	DK2-DE	Kriegers Flak	DK2-DK1
2020	Flow reference scenario	5,352,963	9,353,217	4,605,909	8,933,293	9,284,768	3,270,587	1,337,600	2,342,861
	Flow implicit scenario	5,431,389	9,322,551	4,638,448	9,090,457	9,361,164	3,400,148	1,405,247	1,617,239
	Difference to reference	78,426	-30,665	32,539	157,164	76,395	129,561	67,647	-725,621
	Percentage difference	**1.5%**	-0.3%	**0.7%**	**1.8%**	**0.8%**	**4.0%**	**5.1%**	**-31.0%**
2025	Flow reference scenario	5,421,608	7,214,397	2,820,133	11,730,034	8,884,998	3,102,312	1,121,833	2,676,270
	Flow implicit scenario	5,418,806	7,227,844	2,800,165	11,876,638	8,591,451	3,416,122	1,289,102	1,581,612
	Difference to reference	-2,803	13,447	-19,968	146,604	-293,547	313,810	167,269	-1,094,657
	Percentage difference	**-0.1%**	**0.2%**	**-0.7%**	**1.2%**	**-3.3%**	**10.1%**	**14.9%**	**-40.9%**
2030	Flow reference scenario	5,221,174	8,785,895	2,012,219	11,537,737	9,245,707	3,198,880	1,139,616	2,424,871
	Flow implicit scenario	5,256,653	8,834,231	2,075,562	11,769,415	9,042,537	3,521,308	1,264,082	1,548,664
	Difference to reference	35,480	48,337	63,343	231,679	-203,170	322,429	124,467	-876,207
	Percentage difference	**0.7%**	**0.6%**	**3.1%**	**2.0%**	**-2.2%**	**10.1%**	**10.9%**	**-36.1%**

Table 3 Reference scenario with implicit grid loss on Skagerrak only and flow in scenario with implicit grid loss on the Great Belt Power Link as well (in absolute values, differences in MWh and in percentages, for 2020, 2025 and 2030 modelling).

It is evident from Table 3 that implicit grid loss on the Great Belt Power Link will lead to a decrease in flow on this interconnector and consequently to changes in flow on other connections. For example, the flow on the Great Belt Power Link in 2020 (with implicit grid loss) is expected to drop 31% compared to the reference scenario. This drop in flow will lead to a 13.6 per cent increase in flow in absolute change on the remaining Danish connections. In 2025, implementing implicit grid loss on the Great Belt Power Link is expected to lead to a 41 % decrease in flow on the Great Belt Power Link, which in return will result in an overall increase on the remaining Danish interconnectors of approximately 22 per cent. In 2030, flow on the Great Belt Power Link is expected to drop approximately 36 per cent which will result in an increase of approximately 25 per cent on the remaining connections. The highest increase in flow in all three years is expected to occur on the border between Eastern Denmark and Germany.

The change in flow can also be envisaged with load curves, which is provided in the below Table 4.

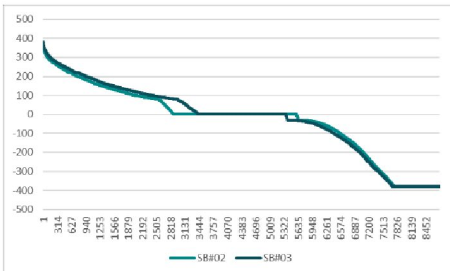
Only the curves for the bidding zone borders DK2-DK1, DK1-SE3, DK2-SE4, DK1-DE and DK2-DE are included in the following table, whereas Annex I includes all load curves for the BID Model Simulation, for the years 2020, 2025 and 2030. In general, the load curve indicates the number of hours with flow of a specific volume in either import direction or export direction, where positive values indicate export and negative values indicate import in the direction of the provided bidding zones above the load curve. The curve named SB#02 is the reference scenario, where implicit grid loss is already implemented on Skagerrak. The curve named SB#03 is the scenario, where implicit grid loss is implemented on the Great Belt Power Link also. It is evident that the largest change in flow therefore is expected on the border DK2-DK1, where implicit grid loss is implemented.

<table>
<tr><th>2020</th><th>2025</th><th>2030</th></tr>
<tr>
<td>DK2-DK1

</td>
<td>DK2-DK1

</td>
<td>DK2-DK1

</td>
</tr>
<tr>
<td>DK2-DE

</td>
<td>DK2-DE

</td>
<td>DK2-DE

</td>
</tr>
<tr>
<td>Kriegers Flak

</td>
<td>Kriegers Flak

</td>
<td>Kriegers Flak

</td>
</tr>
</table>

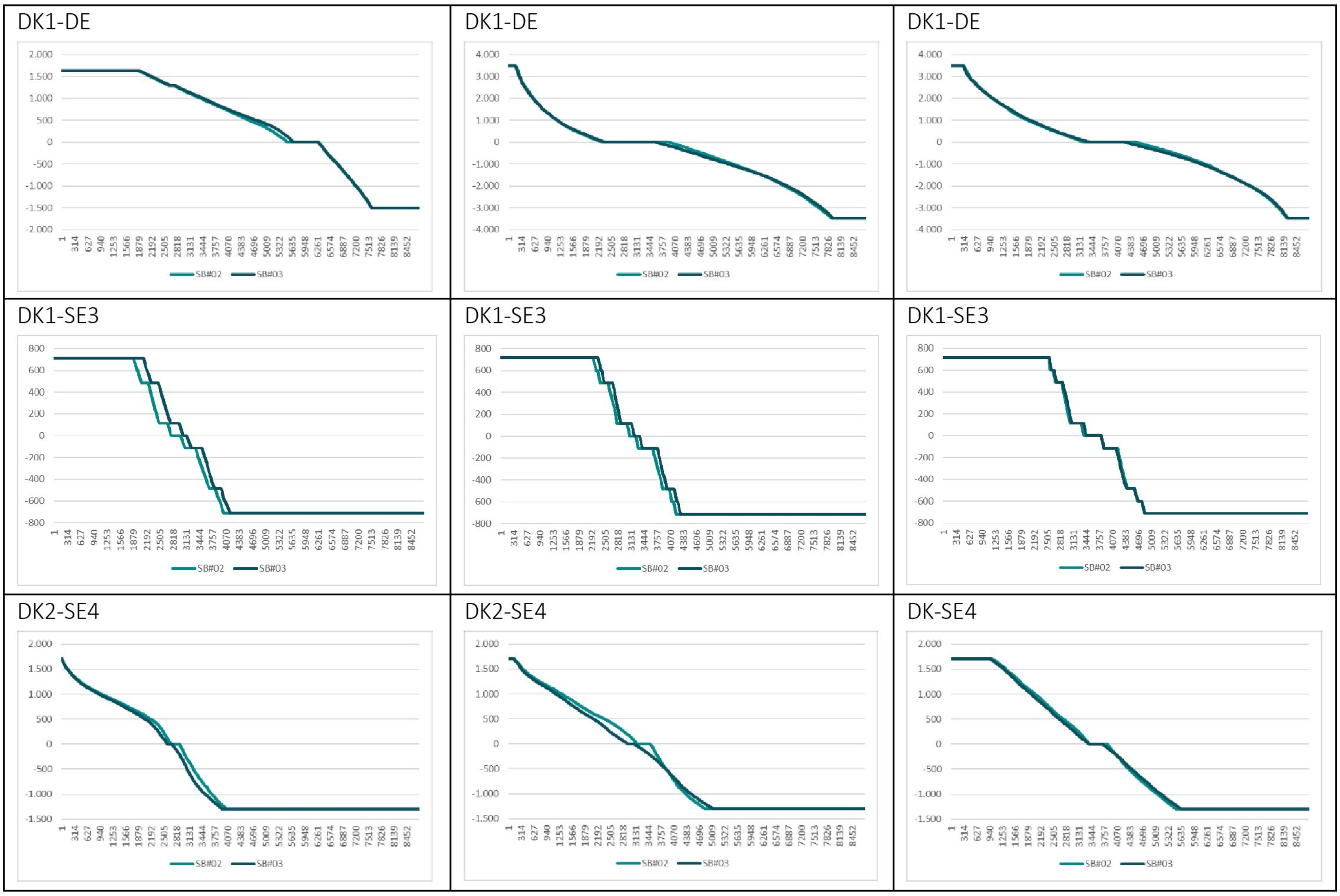


Table 4 Load curve for the years 2020, 2025, 2030 on the borders specified above. SB#02 is the reference scenario, where implicit grid loss is already implemented on Skagerrak with 2.4 % loss factor. The curve named SB#03 reflects the scenario, where implicit grid loss is implemented on the Great Belt Power Link, with a loss factor of 1,5% and Skagerrak already has implicit grid loss with 2,4%.

Table 4 indicates that there will be around 2,000 more hours of zero flow on the Great Belt Power Link, which was mostly flow directed towards DK2 in 2020 in the scenario without implicit grid loss on the Great Belt Power Link. As for the load curve in 2025, the BID model indicates that there are about 3,000 more hours with zero flow on the Great Belt Power Link and these hours are equally divided between flows that would have been classified as import and export in the reference scenario. In 2030, there are about 2,400 additional zero flow hours in the scenario with implicit grid loss on the Great Belt Power Link.

However, as seen on the bidding zone borders DK2-DE (which has a separate load curve for Kriegers Flak), and DK1-SE3, less hours of zero flow are expected on the respective interconnectors with 988 and 127 hours less, respectively, than in the reference scenario with implicit grid loss solely on Skagerrak in 2020. For DK2-SE4, there are 120 hours less of zero flow in 2020.

In 2025, there are approximately 2,000 additional hours of flows differing from zero on both Kontek and Kriegers Flak together in the scenario with implicit grid loss handling implemented on the Great Belt Power Link also. The effect on DK1-SE3 is not significant in 2025, compared to DK1-DE where there are 380 hours less of zero flow, mostly due to a change in the flow importing to DK1. For DK2-SE4, the effect is also insignificant with a decrease in zero flows of around 170 hours.

In 2030, there are approximately 1,500 additional hours of flows differing from zero on both Kontek and Kriegers Flak comparing the reference scenario with the scenario of implicit grid loss handling on the Great Belt Power Link. The effect on DK1-SE3 is also not significant in 2025, with 58 hours less of zero flow in scenario with implicit grid loss also on the Great Belt Power Link, compared to example DK1-DE where there are approximately 400 hours less of zero flow, mostly due to a change of flow in importing direction to DK1, which are divided between importing and exporting flow. For DK2-SE4, there is a decrease in zero flow hours of around 123.

The flow on DK1-DE, DK1-SE3 and DK2-SE4 are insignificantly affected by the implementation of implicit grid loss on the Great Belt Power Link, and the same applies for the remaining interconnectors shown in Annex I. However, the hours with flow on the DK2-DE border will increase in both imports and exports due to the implementation of implicit grid loss on the Great Belt Power Link.

In conclusion, flow changes are not expected to lead to any problems in the system as the changes caused by the implementation of implicit grid loss on the Great Belt Power Link only marginally alters the flow on other connections.

Long-term transmission rights, specifically financial transmission rights

It is important to consider the compensation mechanism, when implementing implicit grid loss on a border that allows auctioning of long-term transmission rights.

HAR rules, article 48 (1) (a) states the following:
"(…) in case of day-ahead Implicit Allocation, including in case of fallback allocation for Implicit Allocation, the price shall be the Market Spread at the concerned Bidding Zone border for the concerned hourly period only in case the price difference is positive in the direction of the Long Term Transmission Rights of the day-ahead Implicit Allocation in which that Cross Zonal Capacity was reallocated, and 0€/MWh, otherwise. If specified in the respective regional or border specific annexes, this price may be adjusted to reflect Allocation Constraints on interconnections between Bidding Zones as defined in Regulation (EU) 2015/1222, Article 23, paragraph 3, where these Allocation Constraints are included in the day-ahead Cross Zonal Capacity allocation process."

This means that financial transmission right (FTR) compensation should be handled with price adjustments, also in the case of curtailments. Thus, the financial transmission right payout is compensated with loss-adjusted day-ahead market spread (LADAMS).

The suggestion for the Great Belt Power Link is to adjust the prices by adjusting the receiving end prices prior to allocation according to the below Formula 1:

"DK1p: Power exchange price on DK1 bidding zone

DK2p: Power exchange price on DK2 bidding zone

ICLF: Interconnector Loss Factor

LAMS: Loss-adjusted market spread on given oriented interconnector.

Loss-adjusted market spread on DK1-DK2 oriented IC

$$_{BDL-DK1-DK2}LAMS = MAX\left[\left(ROUND(DK2_p \times \{1 - ICLF\}; 2) - DK1p\right), 0\right]$$

Loss-adjusted market spread on DK2-DK1 oriented IC

$$_{BDL-DK2-DK1}LAMS = MAX\left[\left(ROUND(DK1_p \times \{1 - ICLF\}; 2) - DK2p\right), 0\right]"$$

Formula 1 Loss-adjusted market spread calculation and compensation for FTR, also in case of curtailments.

If the implicit grid loss application swaps the direction of power (i.e. market spread is too low to cover the loss factor), then the adjusted price is set to the other bidding zone price and resulting market spread is zero.

Intraday market

The functionality for handling implicit losses in the intraday market has not yet been implemented in the Single Intraday Coupling (SIDC). Energinet does not consider this to be an issue as we expect to implement implicit grid loss on the Great Belt Power Link in 2021.

SIDC is currently implementing a prototype, which will then be converted into an actual solution. The solution for implicit loss handling in SIDC is expected to be available by 2021.

The intention of Energinet is to implement implicit loss handling on SIDC also. However, if for some reason, the SIDC implicit grid loss solution is not in place when implicit grid loss goes live on the Great Belt Power Link in day-ahead market, it is possible that the expected efficiency gain can be reduced through arbitrage for the intraday market during this interim period, as indicated in the analysis provided by Statnett and Energinet for the implicit grid loss application on the Skagerrak interconnector, Annex V. However, because any loss in the intraday market will be the same as in the day-ahead market, it will be impossible to come out worse than with the current loss handling approach. At worst, there will be full arbitrage and thus no effect from implicit loss handling in the day-ahead market until the solution is activated in SIDC. However, this is unlikely as the intraday market is used mainly for balancing by the participants responsible for balancing. Thus, any arbitrage between the day-ahead and intraday markets in the interim period are expected to be moderate in any event.

Furthermore, article 23 (3b) of CACM regarding “methodologies for operational security limits, contingencies and allocation constraints” states that “constraints intended to increase the economic surplus for single day-ahead or intraday coupling” can be implemented. This means that an allocation constraint may be implemented if it increases the economic surplus of either the single day-ahead or intraday coupling. As regards the interim period before implicit grid loss is fully implemented on the Great Belt Power Link, the analysis provided by Energinet indicates that the implementation of implicit grid loss on this interconnector will increase the economic surplus of the day-ahead market. Therefore, Energinet concludes that the implementation of implicit grid loss in the day-ahead market prior to the intraday market would be in line with the CACM regulation. As stated above, this risk is unlikely to materialise, and, if it does, it will only be for an interim period until the intraday market solution for implicit grid loss is developed.

Balancing market

The Nordic TSOs are currently implementing a new balancing market, under the Electricity Balancing Guideline (EB GL). The principle underlying the rules on the balancing market and the methodology applied cannot be decided solely by Energinet, as these must be decided jointly by all TSOs and approved by the NRAs, cf. EB GL. The relevant balancing platforms for Energinet will go-live without implicit grid loss handling, yet, analysis of possible implementation is set to continue thereafter.

Energinet may be able to influence the outcome of these analyses to promote the best solution for the Danish Stakeholders but there are no guarantees. Overall development will also play a part in deciding if there will be implicit grid loss in the balancing market going forward.

Future development and Nordic cooperation

Energinet's objective is to implement implicit grid loss on all its HVDC interconnectors in the future. Therefore, Energinet is working to establish close collaborations with the Nordic and other adjacent TSOs to reach agreements on possible future implementation on other HVDC interconnectors to secure the socio-economic benefits that were presented in the common Nordic analyses on the effects of implementing grid losses in the Nordic CCR (see Annex IV).

Effect on other regions

When Energinet decides to implement implicit grid loss with a neighbouring TSO, analyses will be made of the potential consequences on flows that the implementation of implicit grid loss on further interconnectors will have. For the time being, various reports on implicit grid losses assess the effect on flows in the NWE area.

During the public consultation of implicit grid loss on Skagerrak, Energinet received a comment saying that trading energy between Norway and Denmark is likely to become more expensive than trading energy between Portugal and Denmark. However, such trades carry large AC loss costs to be paid by TSOs via tariffs and shared in the ICT process by the TSOs. Implicit grid loss rather aims to correctly reflect loss costs near or at their origins.

Relationship with European legislation

The purpose of CACM is to establish the framework for an efficient European power market and efficient power trading across bidding zone boundaries. Implicit loss handling will make trading via HVDC interconnectors more efficient, thereby contributing to CACM's overall goal.

CACM will lay the groundwork for efficient power trading, and there are no circumstances in CACM, or in relevant methods developed under the CACM, that create obstacles to implementing implicit loss handling on the Great Belt Power Link.

The electricity markets currently see many developments as the implementation of the CACM, EB GL and FCA guidelines proceeds. These have been put forward as an argument for postponing the implementation of implicit grid losses as this is not a regulation requirement. However, the regulations aim to increase the efficiency of electricity markets, which is also the case with the implicit grid loss implementation. Ever since the electricity markets first opened, they have seen constant and rapid development and this will only continue. So, there will never be an optimal time to implement a new methodology such as implicit grid loss. The method has been discussed and analysed several times for many years, and all results point to the fact that there is a socio-economic welfare gain to be achieved.

Energinet's evaluation is based on the BID3 socio-economic analysis model, described in this application, furthermore, the Nordic TSOs' joint report *Analyses on effects of implementing grid losses in the Nordic CCR* of 30 April 2018, also indicates that the Nordic countries can gain a welfare benefit from implementing implicit grid loss handling. This is deemed sufficient to meet the condition within Article 6(1)(c) of CCM for CCR Nordic, as it demonstrates an EU-wide welfare economic benefit of implementing implicit grid loss handling.

Conclusion

Energinet's socio-economic analysis of implementing implicit grid loss on the Great Belt Power Link concludes that there is a socio-economic benefit of DKK 75.39 million over a 40-year period. This socio-economic benefit is created by an increase in both consumer and producer surpluses and a gain from decreasing loss costs on the Great Belt Power Link. However, the congestion income on the link is expected to decrease due to a drop in flow on the link, when the price difference is not large enough to cover the cost of transporting electricity over the connection.

The flow on the Great Belt Power Link is expected to decrease with the implementation of implicit grid loss, which again will lead to a change in flow on other Danish connections. However, besides an increased flow in both import and export on the DK2-DE border, any change to flows on the remaining interconnectors is considered insignificant. Thus, the changed flows are not expected to cause any system disturbances.

Implicit grid loss will be implemented in the forward, day-ahead market and as soon as a solution for implicit grid loss handling is available in the SIDC market, it will be activated for the Great Belt Power Link also.

The method for calculating the loss factor is based on the reference flow, which is calculated as the annual median flow for all hours with positive flow. Further, losses are calculated using a top-down model based on a statistical analysis of time series for measurement data (flow and losses) which is used in the calculation of the loss factor of the reference flow.

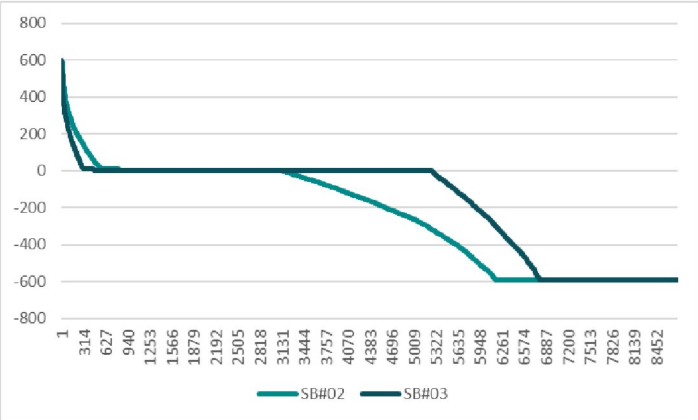
Adjustments to the loss factor will take into account long-term transmission rights, and Energinet will notify the Danish Utility Regulator one month prior to any update of the loss factor. Energinet will inform market participants of any change at least two weeks prior to the implementation date.

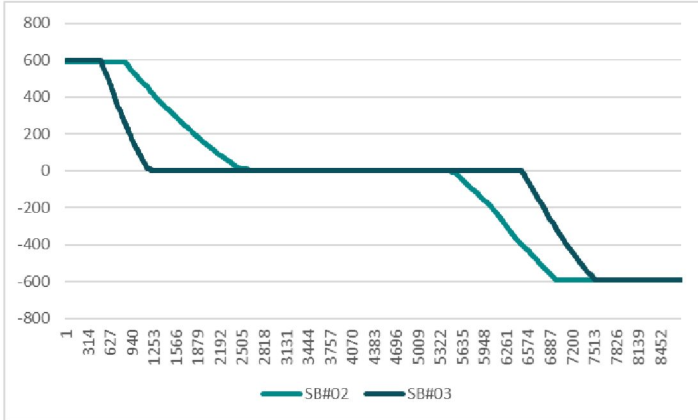
In conclusion, Energinet seeks to realise the socio-economic potential of implementing implicit grid loss on the Great Belt Power Link.

Energinet will hold a public consultation on this methodology approval, and when the consultation responses have been considered, the final methodology approval application will be sent to the Danish Utility Regulator with the expectation that Energinet will be able to implement implicit grid loss handling on the Great Belt Power Link by 2021.

I. Annex

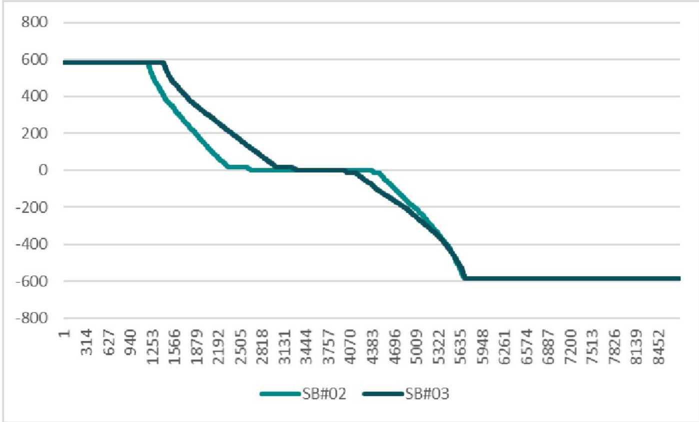
Annex I includes Load Curves for the BID Model Simulation, for the years 2020, 2025 and 2030. The Load Curves indicate the hours of flow in one direction or the other. Positive values indicate export and negative values indicate import in the direction of the provided bidding zones above the load curve. The curve named SB#02 is the reference scenario, where implicit grid loss is already implemented on Skagerrak. The curve named SB#03 is the scenario, where implicit grid loss is implemented on the Great Belt Power Link also. It is evident that the largest change in flow is expected in the DK2-DK1 cross section, where implicit grid loss is implemented. The 2020 curve for Viking Link is not included in the below, as this interconnector has not been built yet.

<table>
<tr><th>2020</th><th>2025</th><th>2030</th></tr>
<tr>
<td>DK2-DK1

</td>
<td>DK2-DK1

</td>
<td>DK2-DK1

</td>
</tr>
</table>

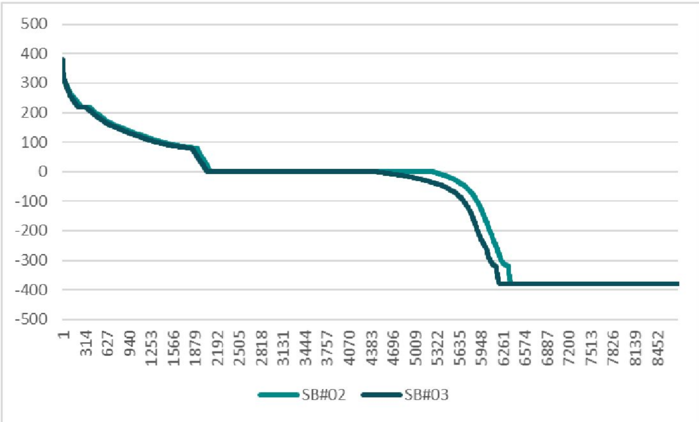
DK2-DE

DK2-DE



DK2-DE

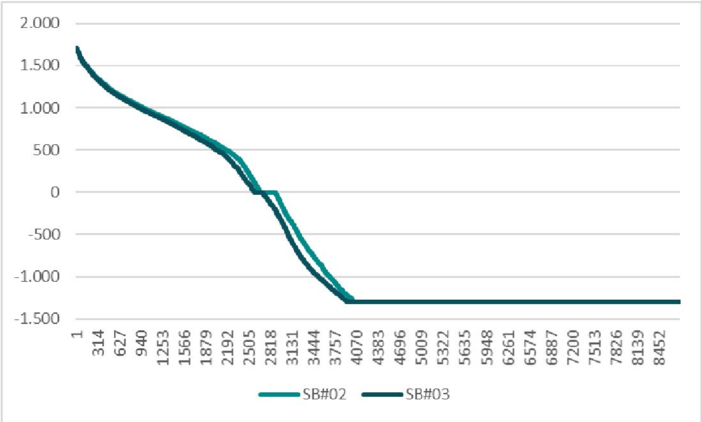
Kriegers Flak



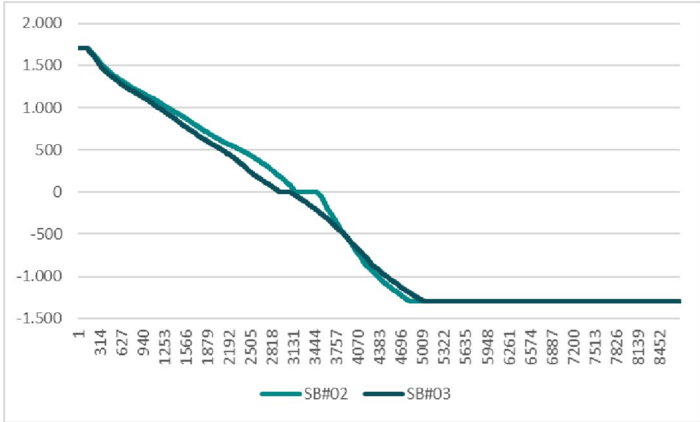
Kriegers Flak

Kriegers Flak

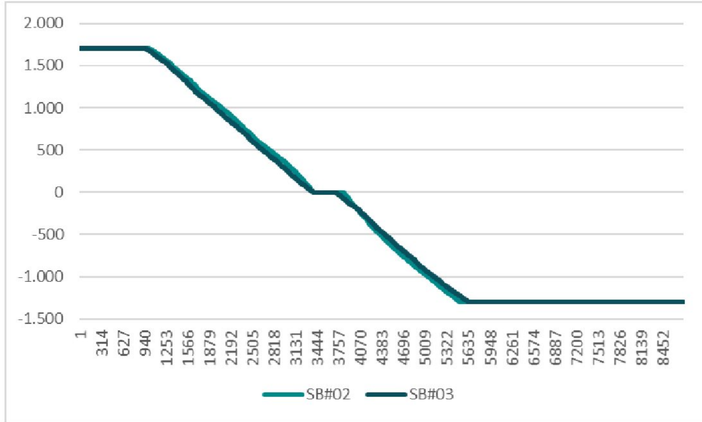
DK2-SE4



DK2-SE4

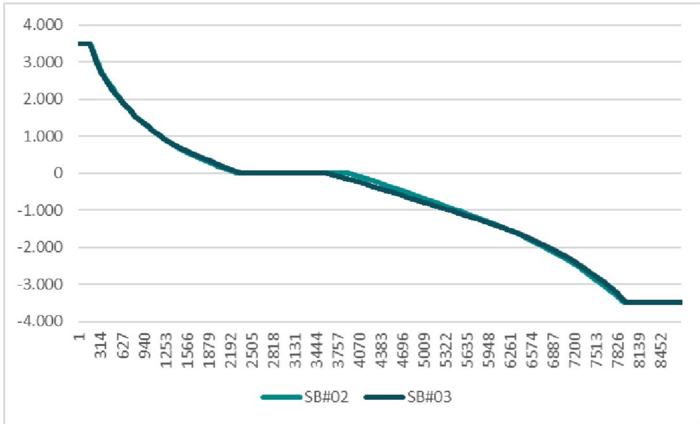


DK-SE4

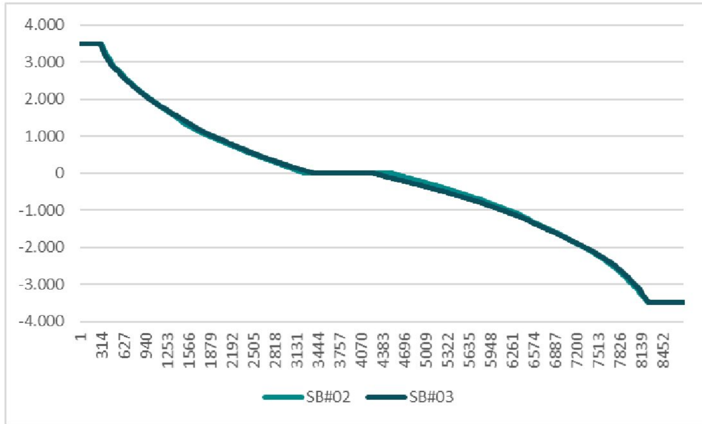


DK1-DE

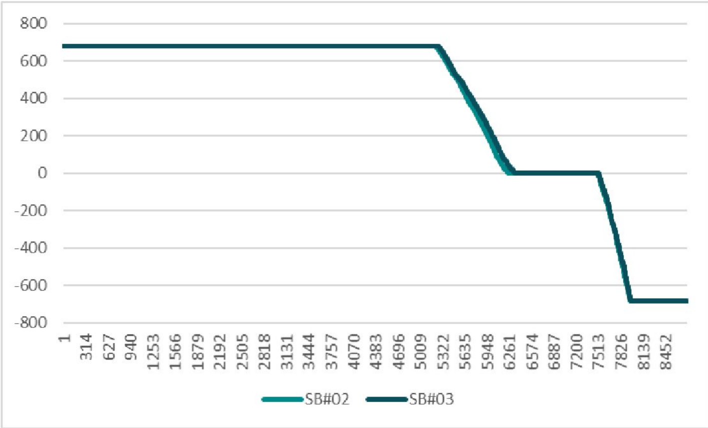
DK1-DE



DK1-DE



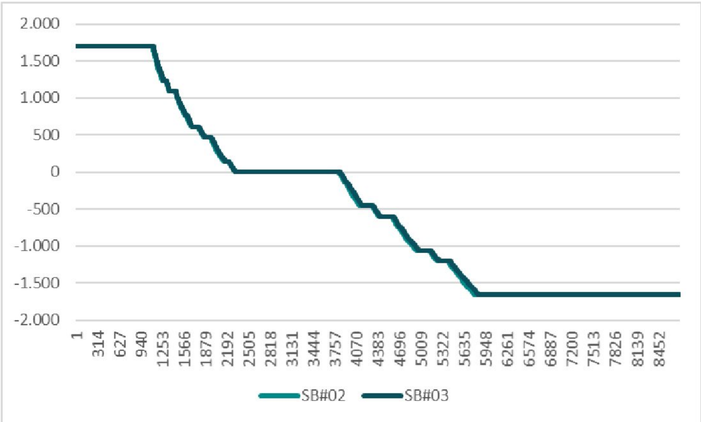
DK1-NL



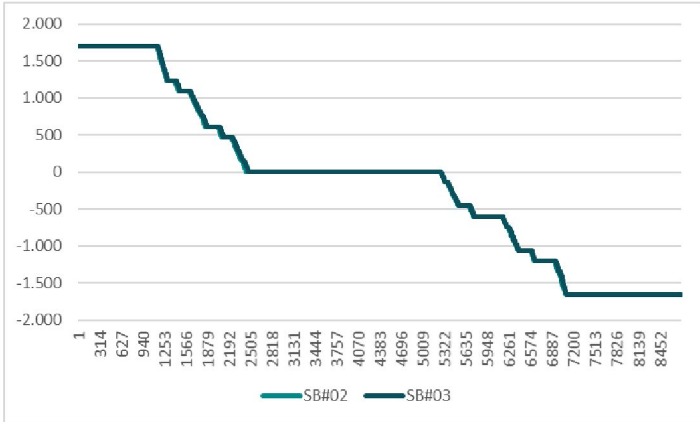
DK1-NL

DK1-NL

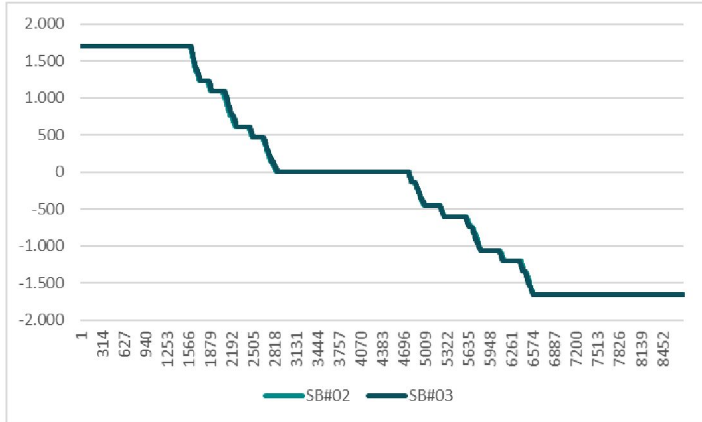
DK1-NO2



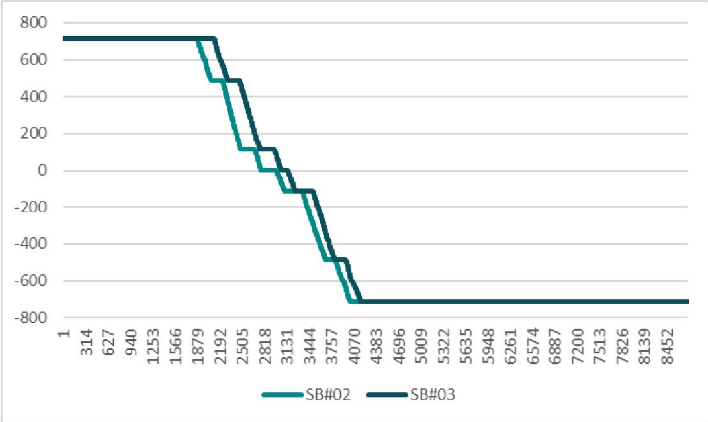
DK1-NO2



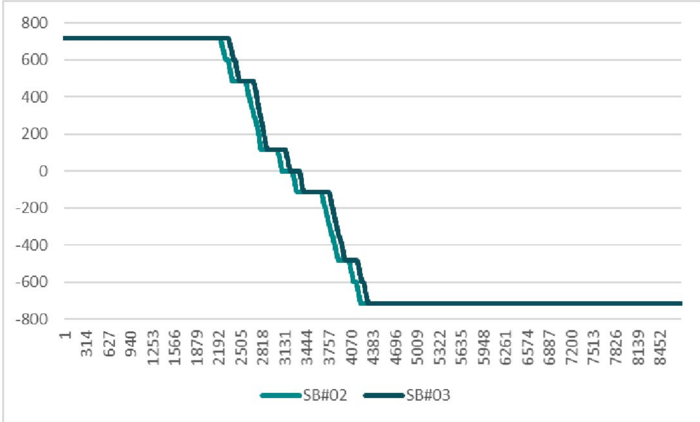
DK1-NO2



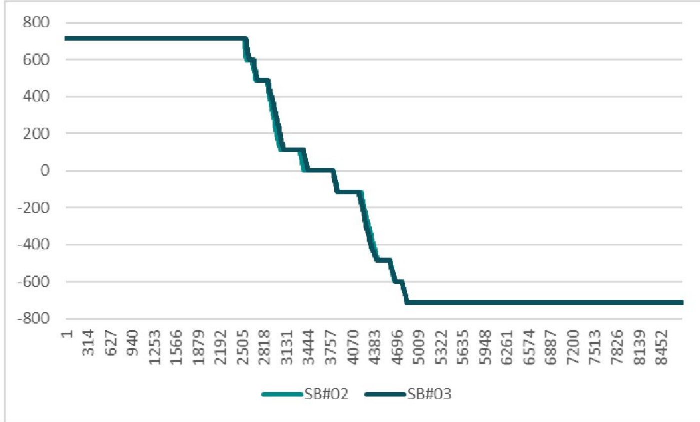
DK1-SE3



DK1-SE3

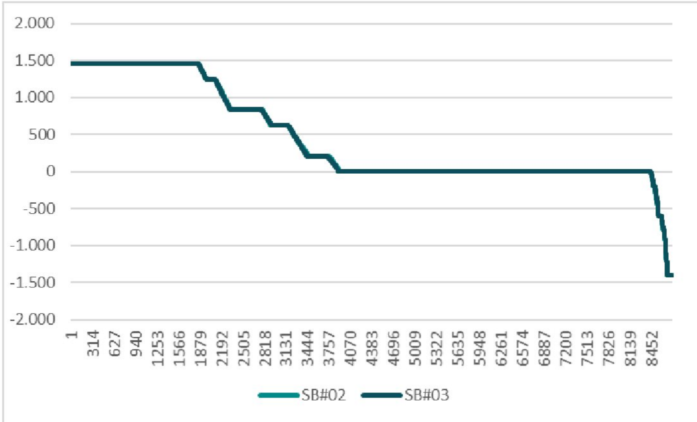


DK1-SE3

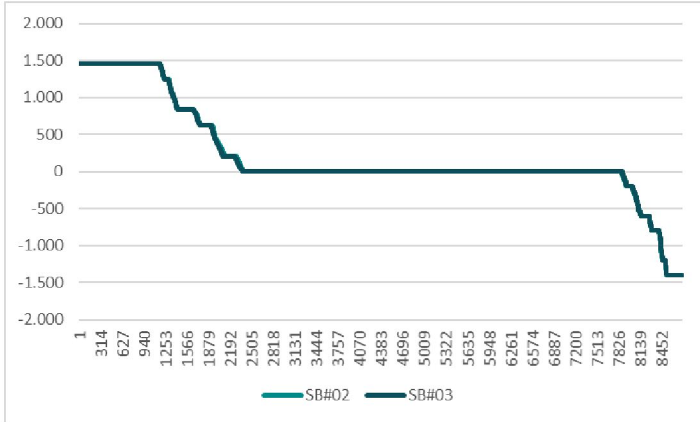


Not implemented in 2020.

DK1-GB



DK1-GB



II. Annex

See attached document which includes the principles for calculating the loss factor, a document prepared by Energinet and Statnett analysing the optimal methodology for calculating the loss factor on the Skagerrak interconnector. This methodology is also applied in the methodology approval for implicit grid loss on the Great Belt Power Link.

III. Annex

MRC study on DC losses attached in a separate document, 2016.

The report responds to market participant and regulatory questions regarding implicit grid loss on HVDC interconnectors in the day-ahead market coupling. The report also clarifies question related to the Inter-TSO compensation mechanism.

IV. Annex

Separately attached, the Common Nordic Analyses on effects of implementing grid losses in the Nordic CCR.

V. Annex

Separately attached, the Arbitrage between the day-ahead and intraday market for Skagerrak.
The conclusion of this analysis can also be applied to the Great Belt Power Link.

VI. Annex

The error of either over- or underestimating grid loss on a given interconnector is the responsibility of the relevant TSO and will be handled in the balancing market.

Below Figure 8 minor shift to a loss factor of 1,5% will lead to both over and underestimation of losses different at flow different than the reference flow.

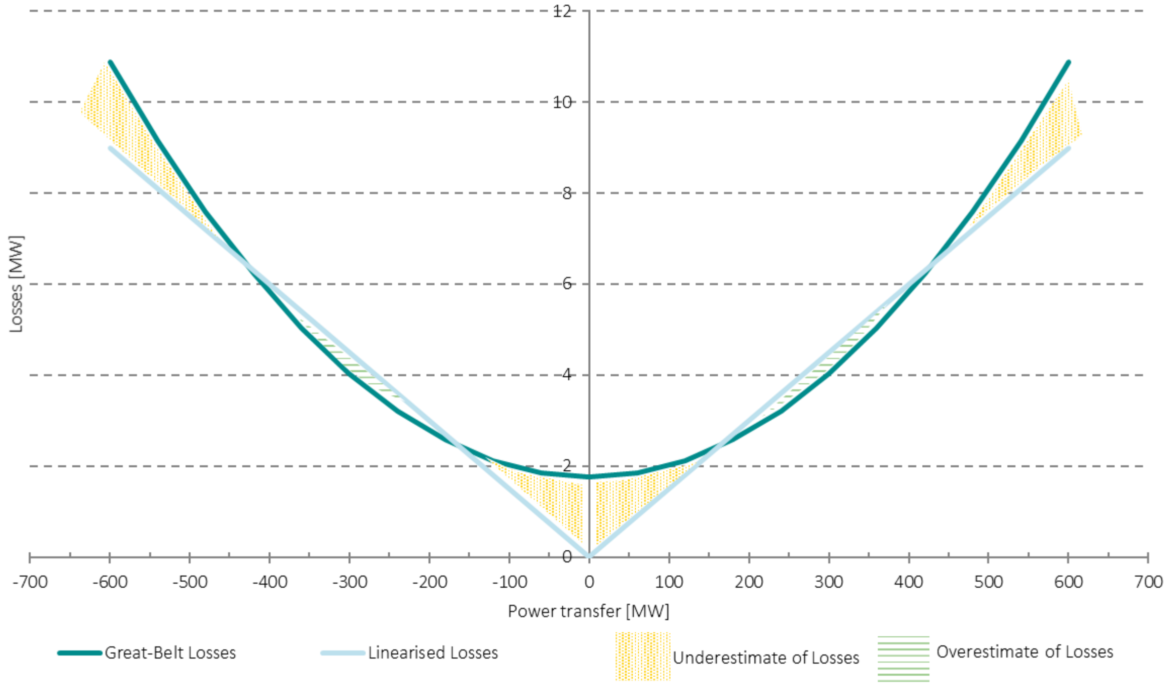


Figure 8 Remaining grid loss illustrated with the area between actual grid losses (dark blue curve) and loss factor of 1.5% in the market coupling algorithm (dashed blue line) for the Great Belt Power Link.