Network Losses Investigation – DNO Boundaries

SSEN and UKPN Collaboration
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Version 1.6

Scottish & Southern Electricity Networks

Summary

Scottish and Southern Electricity Networks (SSEN) and UK Power Networks (UKPN) committed to collaboration in their respective Losses Discretionary Reward (LDR) submissions to Ofgem in 2016. The results of this collaborative working are described in this document. We investigated three different ways that co-operation between UKPN and SSEN could lead to a reduction in network losses. These were: 1) reconnection of SSEN/UKPN LV "convenience customers", 2) possibility of reinforcement links running over DNO borders, rather than only within DNO borders and 3) analysis of losses comparisons between alternative major customer connection offers near the SSEN/UKPN border. In the case of the convenience customer's investigation, the results suggest further work would be unnecessary and there would be little benefit in pursuing the matter further. As an output from the cross-border reinforcement investigation, we have resolved to assist our respective infrastructure planners in sharing information across DNO borders to facilitate potential future cross-DNO interconnections. In the case of the investigated major customer connection, the difference in whole-life losses value of the project was found to be significant, and worthy of consideration for further work.

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Introduction

As part of UK Power Networks' (UKPN) and Scottish and Southern Electricity Networks' (SSEN) Losses Discretionary Reward (LDR) tranche 1 submission, both Distribution Network Operators (DNOs) agreed to collaborate to analyse network losses on their respective networks and investigate ways of reducing losses by working together to gain a holistic, cross-DNO perspective on network losses.

We investigated three areas of possible co-operation: 1) Reconnection of LV convenience customers, 2) Comparison of losses for a major customer connection, and 3) Cross-DNO reinforcement.

"Convenience customers" are LV customers whose properties are located in the geographic footprint of one DNO but whose supply is derived from an adjacent DNO. These connections were typically made on the basis of convenience or connection cost at the time the property was connected.

Discussions with SSEN revealed a particular site in SSEN's network near the border with UKPN's Southern Power Network (SPN) that requires generator support to maintain n-1 compliance. We investigated the possibility of creating a new interconnecting circuit at 33kV to support this site. The site on SSEN's side was Slinfold Primary. The site on UKPN's side was Southwater Primary. Although no specific action needed to be taken, this example highlights the potential value of greater inter-DNO co-operation in reinforcement between substations near DNO borders.

Two major customer connections were identified, each of which could realistically have been connected to either SSEN's network or UKPN's Eastern Power Network (EPN). The UKPN connections were at 33kV and the SSEN connections were at 66kV. We investigated the network losses implications of each connection offer by comparing anticipated additional losses attributable to each customer connection option over the projected lifetime of the new connection.

The investigations focused on three possible areas of losses improvement:

- Connecting customers to adjacent networks when this represented a losses benefit, or re-connecting existing customers connected to adjacent networks to their home network.
- Seeking opportunities for new EHV interconnections to improve losses on adjacent DNO sites.
- Analysing alternative major customer connection designs to improve losses.

LV Convenience Customers

Convenience customers are customers fed from a network outside of that network's designated geographical area.

Using UK Power Network's network records system Netmap, we created a script that automatically determined the length of every LV circuit extending over UK Power Network's geographical area. The circuits corresponded to the convenience customers. The average distance over the border was 69 metres.

The UKPN/SSE border runs through West Sussex and Surrey. We undertook an analysis of the estimated losses of 118 LV convenience connections. These were chosen because they were available as vectorised records in the SPN area. Vectorised records contain the length and rating of the recorded circuits in an easily accessible format, and enable convenient automation of this sort of task. The results of the lengths over the border are shown in Figure 1 below. The maximum length over the border was 335 metres. As can be observed, most of the convenience customers' services are under 100 meters in length.

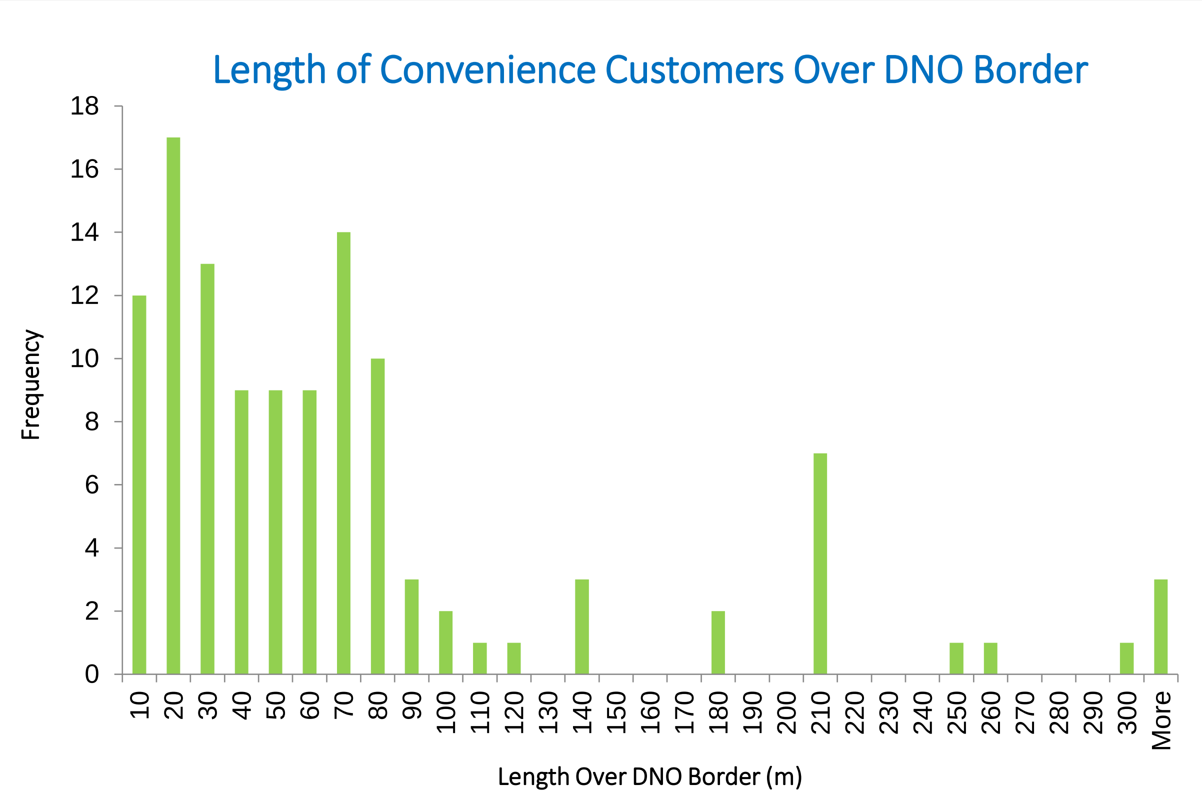

Figure 1: Length of convenience customers over DNO border

The results of the losses calculations are shown in Figure 2 with the assumptions made shown in Table 1 below. Note that these calculations only apply to the length of circuit past the point at which the circuit crosses the DNO border, and as such constitutes a first-pass estimate. A more refined approach would include the circuit back to the relevant distribution transformer, however this approach would introduce considerably more complexity in the scripting phase.

Table 1: Assumptions for convenience customer losses calculation (Caledonian Cables, 11)

Average Distance (m):	Resistivity of LV 16 mm^2 ABC (ohm/km):	Assumed average current (A):	Ofgem Value of Losses (£/MWh):
69	1.91	6.5	48.42

As can be seen in Figure 2, most of the over-the-border losses are clustered below 8 kWh per year.

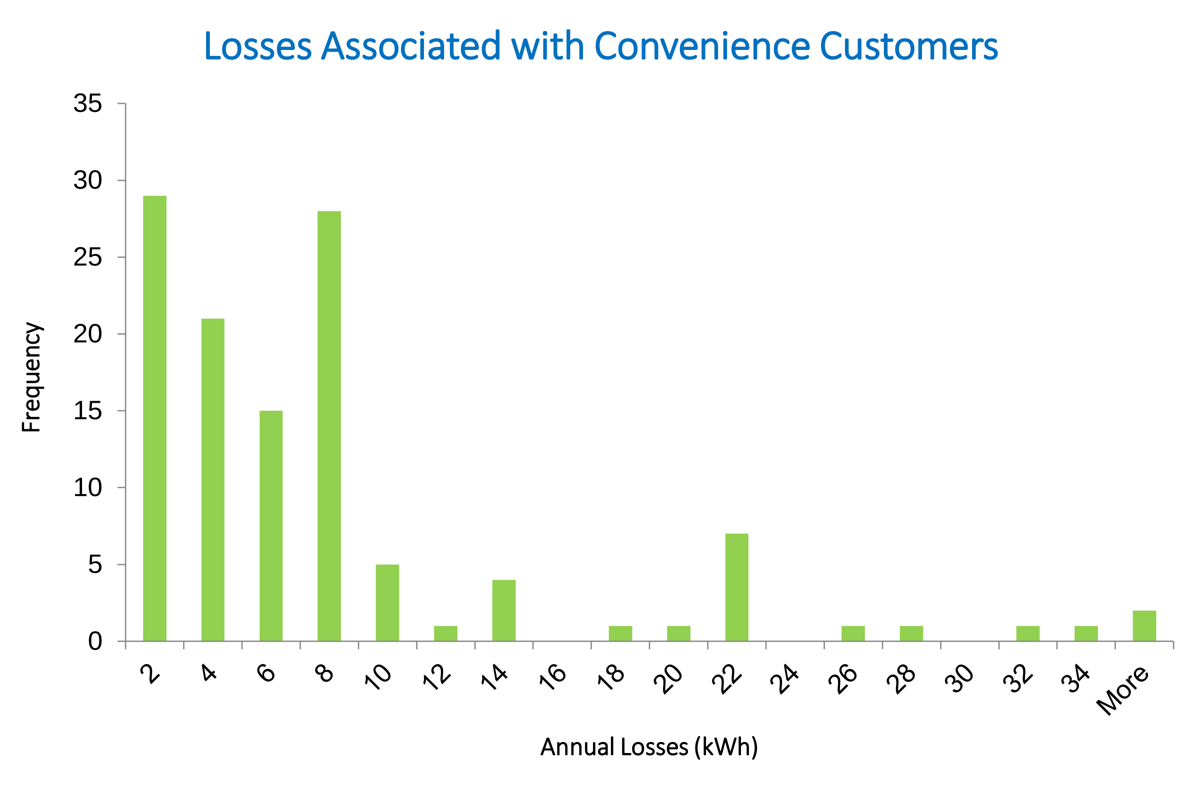

Figure 2: Losses associated with convenience customers

We focused on five specific customers to estimate how the losses would compare if they were fed from the SSE network rather than the UKPN network. This also gave us an opportunity to manually trace back to the distribution transformer in each case, thus yielding more accurate and comprehensive estimates of losses for these connections. The selected customers are shown in Table 2 below.

SSEN's distribution planners took the locations of the UKPN customers and estimated the length of circuit required to connect the convenience customers to an SSEN distribution substation or Overhead Line (OHL). Using existing connection data provided by UKPN, SSEN were able to compare and analyse each customers' losses resulting in the figures presented in Figure 3. As can be seen in the table, the losses delta is in fact positive in most cases, i.e. reconnection would make losses worse. This may reflect the fact that the nearest SSEN distribution transformer or OHL circuit is more distant than the nearest equivalent in UKPN. This in turn might explain why the customer was connected in this way in the first place, as associated connection costs would likely be greater.

Table 2: Selected customers for detailed analysis

		SSEN				UKPN				
Customer NO.	Customer Address	LV cable distance to Distribution S/S [m]	Total Resistance [Ohms]	Total Losses [kWh]	Losses [%]	LV cable distance to Distribution S/S [m]	Total Resistance [Ohms]	Total Losses [kWh]	Losses [%]	Lossees Savings kWh/Year by moving from UKPN to SSEN
1	SU93	368	0.1391	5.1	0.13%	974.2	0.2570	9.5	0.23%	-4.4
2	SU94	350	0.1323	4.9	0.12%	79	0.0360	1.3	0.03%	3.6
3	SU95	830	0.3137	11.6	0.28%	198.8	0.0670	2.5	0.06%	9.1
4	TQ06	1100	0.4158	15.4	0.38%	50.9	0.0519	1.9	0.05%	13.5
5	TQ13	920	0.3478	12.9	0.32%	180	0.0196	0.7	0.02%	12.1

Not only is the loss delta typically negative, the magnitude of the loss delta is quite small. Given the cost of sending operatives to change the connection will be of the order of several hundred pounds at the very least, it is clear convenience customer reconnection will never be economical on the basis of losses. The only case in which the customer experienced an improvement in their notional loss value had a potential saving of 4.4 kWh/year, which is worth only 21 pence per year using Ofgem's £48.42/MWh losses valuation. As such, it is not economical to engage in reconnection.

The information shown in Table 2 above is shown graphically in Figure 3 below.

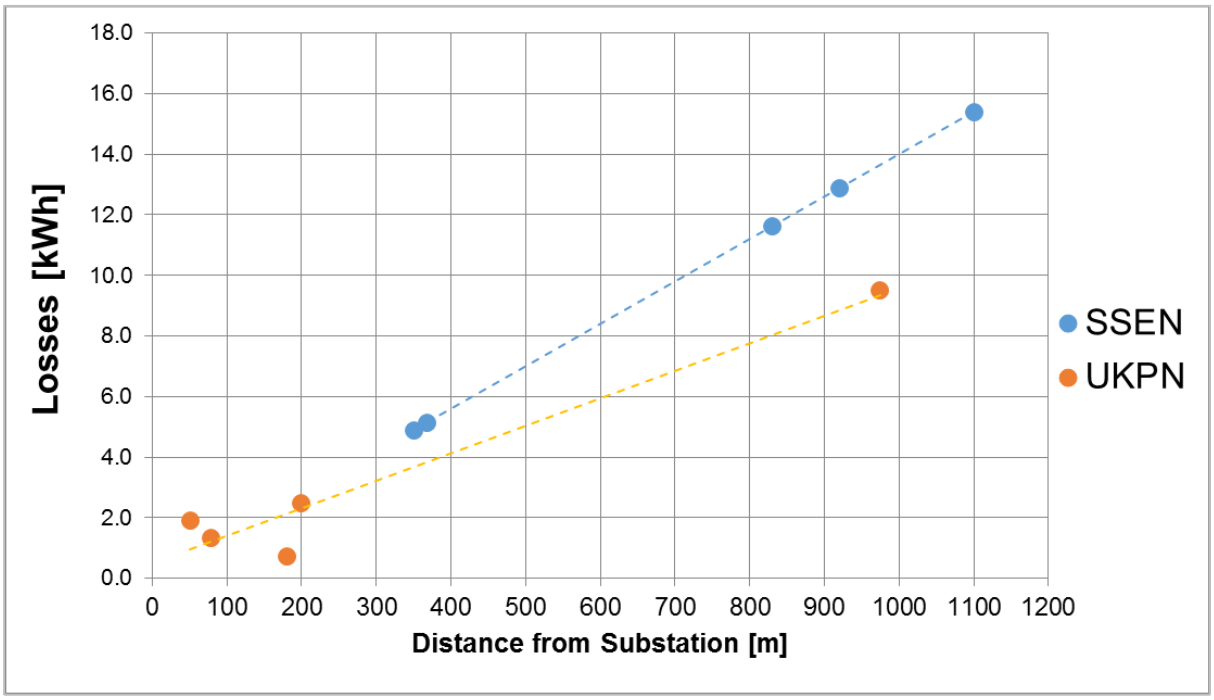

Figure 3: Correlation between distances and losses for five selected UKPN customers shown with hypothetical alternative SSEN connection

In conclusion, we do not believe that changing LV convenience customers' connections will ever be economically justified based on losses alone.

Substation Reinforcement Co-operation (Slinfold/Southwater)

We sought out examples of substations that required reinforcement near the respective DNO borders. One proposed substation was SSEN's West Slinfold 33kV/11kV primary substation. For a period of time West Slinfold was dependent on diesel generation to maintain n-1 security of supply at peak times. Southwater primary is shown in UKPN's network records in Figure 4.

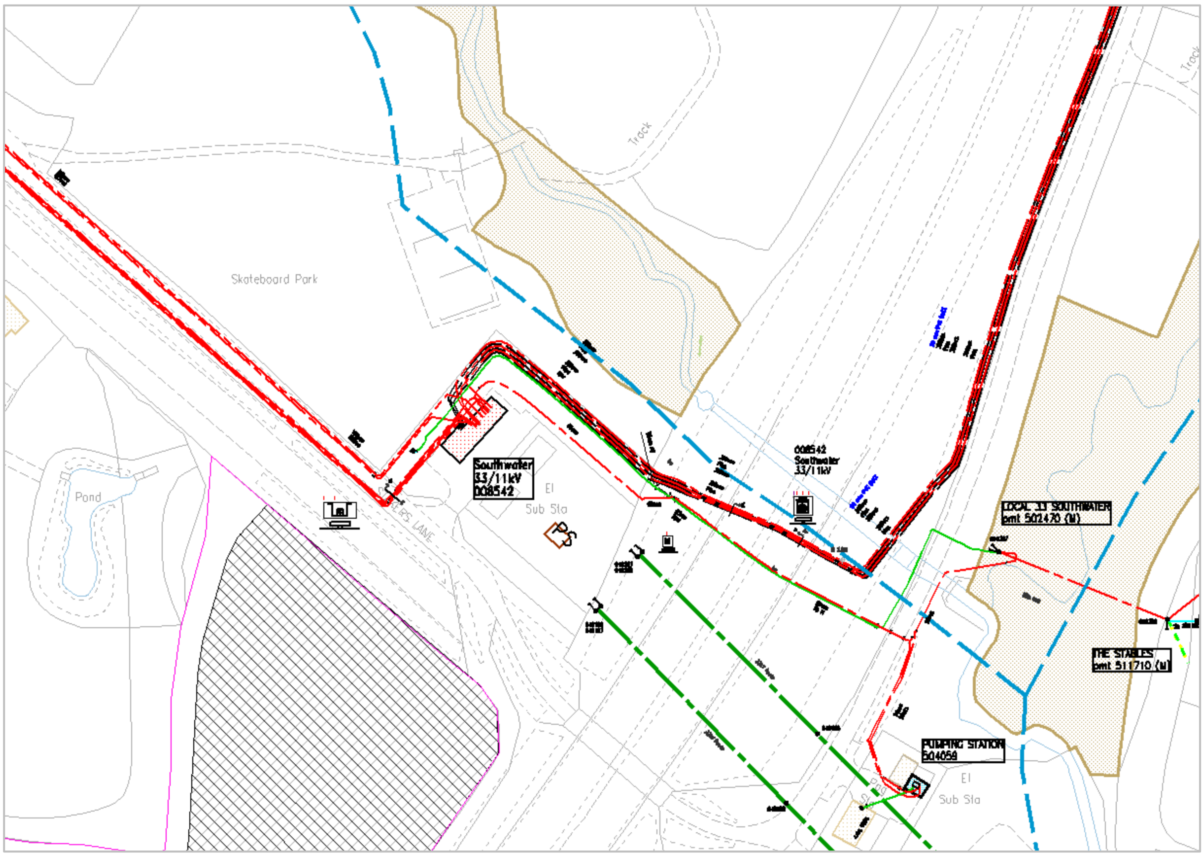

Figure 4: Southwater Primary Geographical Network Diagram

It was proposed that running an interconnector cable between Southwater and West Slinfold would save considerable amounts in CO_2 reduction, due to reduction in diesel generation operation. However, on further investigation we discovered the problem had been mitigated by SSEN using traditional means, thus no action needed to be taken. That said, the scenario offers valid and replicable comparisons to be made. It is also worth maintaining a watching brief on this case to identify additional loss-minimising and prime-cost-minimising cross-DNO reinforcement opportunities in this area. As part of the learning from this investigation, we have resolved to swap information about site locations between the infrastructure planning functions in SSEN and UKPN, so that both groups are aware of the constraints on adjacent networks. Specific criteria has been set by SSEN and UKPN to enable us to effectively identify schemes with potential for economic loss-minimising and prime-cost-minimising cross-DNO reinforcement. We hope that this will cultivate continued cross-DNO engagement and potentially actively improve losses. This also increases the possibility of high-upside alternatives for reinforcement going forward.

Major Customer Connection Loss Comparison

We investigated two major connection inquiries to both SSEN and UKPN for two sites near the UKPN/SSEN border. To ensure commercial confidentiality, this report will only make reference to the connection load rating, and the works required. The name of the customers and the grid sites at which the connections connect are anonymised. No costing information was exchanged between UKPN and SSEN. In summary, the two connections on the UKPN side consist of:

- 20 MVA via two 33kV breaker extensions at “H” Grid, with 5.5 km of new 33kV cable to customer site
- 45 MVA via upgraded grid transformers at “L” Grid, with 3.1 km of new 33kV cable to customer site

The equivalent SSEN connections were as follows:

- 20 MVA via two 66kV breaker extensions, with 4 km of new 66kV cable to customer site
- 45 MVA via two 66kV breaker extensions, with 1 km of new 66kV cable to customer site

In each case, the connection load was assumed based on the customers’ projected usage patterns. We calculated the additional losses attributable to these connections on the distribution network. The connection losses were calculated using the resistances and lengths of new stretches of cable, and the additional load on the upstream 132kV network to the Grid Supply Point (GSP). Note that in the case of the 45 MVA connection for SSEN, their 66kV busbar was fed directly from National Grid, so no 132kV losses consideration was included in that calculation. We were unable to include National Grid losses as we lacked visibility of the relevant existing load flows. Given the results of this exercise, incorporating National Grid losses into consideration would be a useful next step for further investigation. However, for this analysis the National Grid losses were assumed to be similar irrespective of which set of connections were accepted. The results of the calculations are shown below in Table 3 and Table 4.

Table 3: Losses delta for “H” Grid

New circuit	UKPN	SSEN
Connection power level (MVA):	20	20
Voltage level:	33kV	66kV
Required maximum load (amps):	350	174.96
Length of new cable (km):	5.5	4
Resistance of cable/km (ohms/km):	0.08	0.101
Reactance of cable/km (ohms/km):		
Resistance of individual circuits (ohms):	0.44	0.404
Number of circuits:	2	2
Total resistance of parallel circuits (ohms):	0.22	0.202
Number of grid transformers:	2	2
Grid transformer fixed losses (ignored) (kW):	132.3	
Grid transformer 132kV resistance (ohms):	0.8112	
Grid transformer 33kV resistance (ohms):	0.03	
Daily grid transformer variable 33kV losses delta (Wh):	196,396	
Daily grid transformer variable 132kV losses delta (Wh):	574,883	-
Daily circuit energy loss (Wh):	1,401,939	321,662
Annual total energy loss due to TX and new circuit (Wh):	793,224,391	117,406,495
Annual loss value @ £48.42/MWh	£ 38,407.92	£ 5,684.82
Discount rate:	3.5%	3.5%
Years considered for NPV calculation:	4	4
NPV of loss @ given discount rate for number of years:	£ 141,075.35	£ 20,880.80
Existing circuit back to GSP		
Voltage level:	132kV	66kV
Required maximum additional current (amps):	87.5	174.954
Length of circuit (km):	7.531	4.17
Resistance of circuit/km (ohms/km):	0.175	0.076
Reactance of circuit/km (ohms/km):		
Resistance of individual circuits (ohms):	1.318	0.317
Number of circuits:	2	2
Additional current per circuit (amps):	43.75	87.477
Total resistance of parallel circuits (ohms):	0.659	0.15846
Existing daily energy loss @ 132 kV (Wh):	1,733,463	324,692
Increase in daily energy loss (Wh):	737,152	815,851
Increase in annual energy loss @ 132 kV (Wh):	269,060,446	297,785,657
Total additional annual energy loss value:	£ 51,408.93	£ 20,073.83
NPV of total additional loss @ given number of years:	£ 188,829.06	£ 73,732.75
Difference between SSEN and UKPN for given number of years:		£ 115,096.31

Table 4: Losses delta for "L" Grid

New circuit	UKPN	SSEN
Connection power level (MVA):	45	45
Voltage level:	33kV	66kV
Required maximum load (amps):	787.5	393.66
Length of new cable (km):	3.1	1
Resistance of cable/km (ohms/km):	0.06	0.0489
Reactance of cable/km (ohms/km):		
Resistance of individual circuits (ohms):	0.186	0.0489
Number of circuits:	2	2
Total resistance of parallel circuits (ohms):	0.093	0.02445
Number of grid transformers:	2	2
Grid transformer fixed losses (ignored) (kW):	94.7	
Grid transformer 132kV resistance (ohms):	1.068	
Grid transformer 33kV resistance (ohms):	0.03	
Daily grid transformer variable 33kV losses delta (Wh):	279,384	
Daily grid transformer variable 132kV losses delta (Wh):	1,960,601	-
Daily circuit energy loss (Wh):	3,000,229	197,102
Annual total energy loss due to TX and new circuit (Wh):	1,912,678,450	71,942,355
Discount rate:	3.5%	3.5%
Years considered for NPV calculation:	4	4
NPV of loss @ given discount rate for number of years:	£ 340,170.81	£ 12,794.98
Existing circuit back to GSP		
Voltage level:	132kV	66 kV
Required maximum additional current (amps):	196.875	393.648
Length of circuit (km):	1.77	0
Resistance of circuit/km (ohms/km):	0.137	0
Reactance of circuit/km (ohms/km):		
Resistance of individual circuits (ohms):	0.242	0.000
Number of circuits:	2	2
Additional current per circuit (amps):	98.4375	196.8239554
Total resistance of parallel circuits (ohms):	0.121	0.00000
Existing daily energy loss @ 132 kV (Wh):	166,356	-
Increase in daily energy loss (Wh):	261,807	-
Increase in annual energy loss @ 132 kV (Wh):	95,559,732	-
Total additional annual energy loss value:	£ 97,229.34	£ 3,483.45
NPV of total additional loss @ given number of years:	£ 357,131.06	£ 12,794.98
Difference between SSEN and UKPN for given number of years:		£ 344,336.07

It is notable that the difference in whole-life losses value between UKPN and SSEN for connecting the 45 MVA connection represents a significant amount of additional losses over the projected connection lifespan. In financial terms this comes to £344,000. This is mainly because the SSEN connection is at 66kV rather than 33kV, and is connected directly to the 245kV to 66kV supergrid site on SSEN's side, and so there is no corresponding losses delta on the 132kV side. The 20 MVA connection was calculated to have a lower losses delta value of £115,000 over the anticipated connection lifespan.

This analysis incorporated consideration of the losses impact of the additional load on the 132kV network, as well as the losses on the new cables introduced by the connection. It is proposed that options for future major projects and major connections are subjected to a network loss analysis of this kind in the optioneering stage. In the specific case of major connections, it is proposed that the customer be made aware of the whole-life net present value cost of the network losses, along with the prime costs of connection. Similarly, for major projects, the whole-life net present value cost of network losses of different project solutions should be considered at project initiation and be incorporated into the overall cost-benefit consideration of the project as a whole.

We note that at present Line Loss Factors (LLF) are calculated for major customers (i.e. customers connected at voltages 22kV and above) on a yearly basis, and are based on metered measurements taken for that customer in the preceding year – or on the basis of area-specific templates in the case of new connections. Customers are not presented with indicative LLFs as part of their initial connection offers.

Conclusions

We conclude that there is little value in pursuing alteration of existing convenience customers on the basis that the associated losses will never amount to an economic value sufficient to justify such changes. Moreover, many instances of convenience customers are in fact already connected in such a way as to minimise losses.

However, our findings suggest that DNO infrastructure planners near DNO borders should consider alternatives to traditional intra-DNO reinforcement by considering interconnection (or any other valid solution) with neighbouring DNOs. SSEN and UKPN have agreed to share the learning in this report with our respective infrastructure planning and distribution planning engineers, and encourage them to communicate with their opposite numbers in the adjacent DNOs to identify opportunities for cross-DNO reinforcement if this makes economic and engineering sense. We will also commit to an ongoing series of information sharing workshops between ourselves on a half-yearly basis to collate and share potential cross-DNO reinforcement opportunities.

Finally, we investigated a pair of major connections customers that could connect to either SSEN or UKPN. We determined that the difference in the whole-life value of network losses was significant and we believe that this merits further investigation into how the existing connection charging methodologies treat losses. We will also discuss major connections at our half-yearly inter-DNO workshops, based on our understanding major connection projects near the border.