SP Energy Networks

October 2017

Transmission Losses Report 2017

SP ENERGY NETWORKS

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1. INTRODUCTION

Special condition 2K of the SP Transmission plc (SPT) transmission licence requires SPT to publish an annual transmission losses report detailing the present level of transmission losses and progress on our strategy to minimise transmission losses.

Based on metered data provided by the System Operator (SO) the total losses on the SPT network, i.e. the difference between energy flowing into and out of our network, for the period between 1 April 2016 and 31 March 2017 were 639 GWh[1], representing an operational cost of approximately £38.34m[2]. Energy loss on the SPT network, as a percentage of the total energy transmitted, was 2.12% for the year up to March 2017.

In preparing this report, the SO has indicated that the SPT losses values they provided to us for 2014/15 and 2015/16 were incorrect. The revised values were not available in time for inclusion in this report.

The following sections of this report discuss a number of factors that have an impact on this number and how it might change in future. It also outlines progress made towards improving the losses-related performance of our network and the impact of new technologies that we are deploying in line with our Transmission Losses Strategy published in December 2013.

2. KEY FACTORS THAT INFLUENCE SPT TRANSMISSION LOSSES

2.1 Increased network power flows

Based on our latest system models, the losses on the SPT network with winter peak planning transfers are estimated to be around 117 MW[3] in winter 2017/18. The winter peak planning transfer condition for 2017/18 includes the Western Link, which provides a DC connection between Hunterston in the SPT area and Flintshire Bridge in north Wales. The SPT share of DC link losses, when operating at full power, is estimated to be 20 MW. The total value also includes losses in generator transformers, which are not owned or maintained by SPT but are included in the model used for analysis. Total transformer losses are 32 MW, of which 13 MW are generator transformer losses. The remaining losses (about 52 MW) can be attributed to overhead lines, cables and other equipment.

Increased renewable generation connections in Scotland lead to increased peak network transfers and therefore to higher losses. A significant change that occurred in March 2016, just before this reporting period, was the closure of Longannet power station in Fife. This had a peak output of 2.4 GW and therefore a strong influence on power flows on the SPT network. Despite power station closures like Longannet, the increase in network power transfers due to new renewables is the largest contributor to the expected increase in transmission network losses.

[1] The level of Transmission Losses from the licensee's Transmission System, measured as the difference between the units of electricity metered on entry to the licensee's Transmission System and the units of electricity metered on leaving that system as per licence special condition 2K.4 (a).
[2] In assessing the financial value of losses we have assumed £60/MWh, which is the value generally used in our cost benefit analyses.
[3] Last year, we reported winter peak planning losses of 125 MW for 2016/17 and losses of 111 MW were expected for 2017/18. However, significant fluctuations in peak losses can arise due to changing demand and generation background assumptions.

Losses are proportional to circuit resistance, but also proportional to the square of the current flowing in those circuits. In other words, halving the resistance of a circuit will halve the losses in that circuit, but doubling the current will increase the losses by a factor of four. That means that if it has been possible to halve the resistance in a circuit by using lower-loss conductors and/or increasing the number of conductors in the bundle, a 40% increase in current neutralises the benefit of the reduced circuit resistance.

Against a background of increased network transfers, achieving a reduction in total network losses would not be economic or efficient. However, we are working to reduce the losses associated with each unit of energy transmitted across the SPT network by considering losses and wider environmental impacts carefully when evaluating options for transmission reinforcements or asset replacement. For example, the cost benefit analysis we perform takes account of what can be achieved with options like low loss transformers. This feeds into decisions on network development prompted by asset condition, customer connections or other reasons. In general, the cost of avoided losses alone is unlikely to justify the replacement or upgrading of a circuit or transformer.

2.2 Increased volume of embedded generation

Large and small embedded generation has the effect of offsetting demand whilst it is generating, normally reducing the current through grid supply transformers and associated feeder circuits. At some grid supply points, the volume of embedded generation is significant and leads to a power flow from the grid supply point to the transmission network, potentially up to the available capacity limit. In some circumstances this might actually result in higher losses than without the embedded generation. Over the next few years, such conditions are only expected under high-wind conditions and will not exist for extended periods of time. As embedded generation generally offsets demand, it is normally expected to lead to a reduction in equivalent grid supply point demand and therefore a reduction in grid supply point transformer losses.

2.3 Changes in load characteristics

Over the next few years, a substantial reduction in reactive power demand at grid supply points is predicted. In the SPT area, more than 90% of grid supply points currently have a power factor of 0.95 or better. By 2020, this is expected to improve to the extent that 90% of grid supply points will have a power factor of 0.98 or better. This improvement in power factor leads to a small reduction in current and therefore a small reduction in losses[4], mainly associated with transmission feeders and grid supply point transformers.

In combination with embedded generation, the pattern of load on the network determines the time profile of power that is carried on the transmission network. Given that losses are proportional to the square of the current, a ‘peaky’ profile will result in more losses overall than a ‘flat’ profile that delivers the same amount of energy. Thus, changes in load, or embedded generation, that result in higher peaks in power transfer even if total energy transfer remains the same, will result in higher losses. The overall load profile shape is outside of the control of SPT but is another factor that influences losses on our network.

[4] Assuming constant active power, this change in power factor leads to a load current reduction of about 3%. Losses are proportional to the square of the current. For example, a transformer with a load loss of 50 kW at 0.95 power factor, will have losses of 47 kW if the power factor of the load is improved to 0.98; a reduction of 6%.

3. THE IMPACT OF ASSET REPLACEMENT

3.1 Transformers

When procuring transformers, we consider an estimate of the total cost of ownership in order to determine the most economic purchase. This evaluation recognises both the purchase price of the transformer and the transformer losses, by capitalising the cost of these losses over the expected life-time of the transformer[5].

Modern transformers have considerably lower losses when compared to transformers that have been in service for many decades. As an example, consider Devonside GT2 (90 MVA, 132/33 kV). The old transformer was installed in 1972. It had no-load losses of 50 kW and an equivalent short-circuit resistance of 0.079 Ohms. The new transformer installed in 2016 has no-load losses of 19.09 kW and a short-circuit resistance of 0.051 Ohms.

Although the no-load losses are reasonably constant while the transformer is energised, the load losses are a function of the transformer loading. By considering the loading of the transformer over one year, a comparison of losses associated with the old and new transformers is possible. It is estimated that the old transformer dissipated 563 MWh over the year before it was replaced. Assuming a cost of £60/MWh, this amounts to an annual cost of £33.8k. Assuming that the new transformer will be subjected to the same loading pattern, it is estimated to dissipate a total of 248 MWh at a cost of £14.9k. Therefore, the new transformer delivers an annual saving of around £18.9k due to avoided losses.

3.2 Overhead lines

On overhead lines, modern conductors offer a number of improvements over older types including a small reduction in losses. In the SPT area a typical example is the replacement of twin Zebra (400 mm^2 Aluminium Conductor Steel Reinforced (ACSR)) conductor bundles with twin Totara (425 mm^2 All Aluminium Alloy Conductor (AAAC)). The old “Standard Conductivity” Zebra conductor has a resistance of 67.4 μΩ/m while the new “Extra High Conductivity” Totara conductor has a resistance of 62.5 μΩ/m, a reduction of 7.3%.

However, asset replacement on overhead lines also illustrates how increasing power flows across the SPT network may lead to higher losses. One approach to increasing network capacity is for overhead line routes to be upgraded with new conductor technology that can be run at much higher temperatures, e.g. 190°C. This allows the same tower routes to carry much higher amounts of power, and thereby accommodate the growth in renewable generation, and while the higher temperature means higher losses, the need to build new or rebuild existing overhead line towers is avoided.

Losses are also affected by the upgrading of circuits from 275 kV to 400 kV, as was completed in 2016/17 on circuits between Strathaven and Smeaton. For the same power flow, operation at a higher voltage will mean lower current and so lower losses. However, the nature of the interconnected network is such that the higher capacity circuit is likely to carry more power than the circuit it replaced, offsetting the reduction in losses. Significant upgrades, like that between Strathaven and Smeaton, often mean fundamental changes to the network toplogy so it is not practical to calculate before and after values for losses. In the

[5] Appendix A-20 of Specification for Transmission System Double Wound Transformers (TRAN-03-022, Issue No. 7) and Specification for Transmission Autotransformers (TRAN-03-024, Issue No.5).

present context, upgrades to the network like this are primarily driven by the increase in power transfers due to the connection of new renewable generation.

3.3 Shunt reactors

Similar to transformers, when procuring shunt reactors, we establish the total cost of ownership in order to determine the most economic purchase. This evaluation recognises both the purchase price of the reactor, as well as reactor losses, by capitalising the cost of these losses over the expected life-time of the asset.

We are currently replacing a number of shunt reactors and installing new devices on our network. Although losses in these devices are unavoidable, we aim to minimise these as far as economically possible. At most sites we have decided to use air-cored reactors, which do not have an iron core and therefore do not exhibit the associated iron losses. Our existing 33 kV, 60 MVAr shunt reactors were installed in the mid-1960s and typically have losses of 240 kW when energised. Modern shunt reactors, such as those being installed at Coalburn, Eccles and Elvanfoot, of a similar rating have losses in the order of 160 kW. Note that shunt reactors are brought into service only when required, such as during light-load system conditions to limit excessively high voltages. Although system conditions require increasing use of reactive compensation, the duration for which shunt reactor losses are present on the system is typically less than a transformer, which is normally energised all of the time and therefore always presents at least a no-load loss.

4. NEW TECHNOLOGIES

4.1 Series compensation

We recently installed four series capacitors on the Anglo-Scottish interconnector circuits. Tenders for this equipment were evaluated on a whole-life cost basis and losses were included in this calculation. Tenderers were required to submit a detailed loss calculation report, considering a range of operating conditions and the impact of component tolerances. For tender evaluation, the losses at 50% load and nominal component values were used, as this was considered a realistic operating point for comparison on an intact network.

We opted for fixed series capacitors with passive bypass filters for sub-synchronous resonance mitigation. The losses in these installations are more susceptible to changes in system frequency and variations in component tolerances than competing technologies such as thyristor controlled series capacitors. However, under normal operating conditions, the losses were assessed as being lower than those of alternative options.

The final tender evaluation involved careful consideration of the sub-synchronous resonance risks, balanced against cost, a high availability requirement, losses and environmental impacts such as noise emission. The losses of the winning bid were assessed as approximately 70 kW per installation lower than the nearest competitor. These losses led to a difference in whole-life cost contributions in the order of £100k per series compensation installation.

Note that when the series capacitors are not required for network operation, i.e. at time of lower power transfer, they will be switched out (by closing a bypass circuit breaker). Although this is primarily an additional sub-synchronous resonance mitigation measure, it also eliminates losses from the series compensation equipment during such periods. An estimate of this out-of-service time was included in the calculation of the cost of losses.

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It is important to understand that the series capacitors do not have a direct impact on the losses associated with the circuits in which they are installed. Although series compensation has the effect of reducing the overall circuit impedance, the resistance of the conductors remains unaffected. Series compensation actually allows higher transfers on the existing interconnector circuits, which will in turn lead to higher losses in these circuits. However, this has to be considered against the benefits of an increase of 1100 MW in the capability of the Anglo-Scottish interconnectors, which leads to increased utilisation of renewable forms of generation and a considerable reduction in constraint costs associated with these circuits.

4.2 Shunt capacitors

In recent years we have installed mechanically switched capacitors with damping networks (MSCDNs) at Windyhill, Longannet, Elvanfoot, Moffat and Cockenzie with a combined rating of 1275 MVAr. These devices are switched in and out as required operationally for voltage control or to support the system after a fault. In most cases, the MSCDNs will not be in service for extended periods of time, which helps to minimise power losses from these devices.

The losses in an MSCDN broadly arise from two sources: fundamental frequency (50 Hz) losses and losses due to the presence of harmonic voltages on the network. Under ideal conditions, the losses associated with a MSCDN are not very high, but the 50 Hz losses could rise to over 100 kW per installation due to changes in system frequency or due to component tolerances. Harmonic voltages can lead to significant losses in the damping resistors of MSCDNs. It is difficult to quantify the harmonic losses as harmonic voltages on the network vary considerably. In fact, switching the MSCDN in or out of service will have an impact on the harmonic voltage levels. Under worst-case conditions, the losses in the damping resistor could rise to several hundred kW.

Note that the design of MSCDNs has been standardised to the point where an evaluation of losses at tender stage does not have an impact on the choice of supplier. The variation between suppliers is minimal, depending only on small component-level variations.

4.3 Western Link HVDC interconnector

The Western Link HVDC interconnector is currently being commissioned. The link will connect Hunterston in the SPT area to Flintshire Bridge in the National Grid transmission area and has a rated capacity of 2250 MW. When operating at rated current, the total losses of the link are in the order of 45 MW, which is significantly lower than the losses of an equivalent AC circuit of the same capacity and length. This includes losses in both converters and in the DC cable, but does not include losses in the harmonic filters or the SVC that have been installed at Hunterston as part of this project. It is difficult to predict the total losses of the link, e.g. over a year of operation, as these will depend on the operating point of the link, the operating point of the SVC and the number of harmonic filters and/or reactors switched in.

The Western Link is designed to minimise losses over and above the loss reduction that can be achieved by using HVDC technology instead of an AC interconnector. A good example is if the HVDC station control system detects that a shunt reactor and a harmonic filter (that is not required for harmonic performance) are switched in at the same time, it will switch out both devices to reduce losses. Although the reactive power control system will primarily control harmonics and system voltage, it will manage losses if there is an opportunity to do so.

When we have gained operational experience on the Western Link and have had an opportunity to assess the resulting changes in power flow on our AC network, we will report on the impact of the Western Link on system losses in further detail.

5. SUBSTATION AUXILIARY SUPPLIES

The power supplies to our substations (for protection and control equipment, battery chargers, cooling systems, lighting, heating, etc.) are usually derived from secondary windings on 33 kV neutral earthing transformers. Presently, these supplies are not metered and substation demand, which is a transmission loss, is therefore not accounted for separately. Most equipment at substations is essential and could not be switched off. However, it may be that lighting and room heating for example, could be better controlled. We aim to identify where efficiencies can be made through energy saving measures and will implement these where it is cost effective to do so.

We are currently conducting a project that involves the installation of energy metering at a small number of test sites to support an audit of possible on-site energy-saving measures. The substation sites have been chosen as suitable for developing representative archetype models. The project team, which includes Edinburgh Napier University and Logic Energy, are currently fine tuning their models of the selected substations to fit the building envelope, services, and occupancy, with the aid of the energy logging deployed since July 2017. This forms part of a continual model calibration that will get more accurate as further data is retrieved by the loggers. As part of this calibration process, each substation is also being visited again to confirm exactly what each circuit being logged is powering, which will give an indication of the range of use and potential savings.

Initial results from the data loggers indicate average daily consumptions at the selected substations as shown in Table 1. This has been extrapolated to give estimated annual consumption values but it should be noted that energy consumption will vary greatly through the year, particularly due to changing demands for heating and lighting. Monitoring will continue for a full year and we will report on the findings in our 2018 losses report.

Table 1. Initial results from monitoring of substation auxiliary supplies

Substation	Average daily consumption (kWh)	Estimated annual consumption (MWh)	Estimated annual equivalent cost (assuming £60/MWh)
Dalmarnock	50.60	18.47	£1.1k
Carntyne	146.73	53.56	£3.2k
Braehead	302.54	110.43	£6.6k
Paisley	478.92	174.81	£10.5k
Elderslie	602.09	219.76	£13.2k

One early conclusion is that there is considerable diversity in consumption between the archetypes. Instances have been identified where lighting and heating has been switched on at times and levels inconsistent with substation occupancy or need. Further research during the coming heating season will add to this body of knowledge in respect of control strategies to reduce uncontrolled losses and to mitigate heat losses in respect of the building envelopes. Energy efficient technologies for appliance replacement and potential onsite energy generation are also being considered.

6. OTHER IMPACTS

As described above, for a given flow of power, the reduction of losses implies a reduction in series resistance of equipment or an increase in shunt resistances, such as the no-load losses of transformers. This has two important side-effects:

1. The time constant associated with the DC component of fault currents is increased, leading to more onerous circuit breaker duties. This is particularly significant at many SPT grid supply points, where the fault current is dominated by the characteristics of the grid supply transformers. Here, a reduction in transformer losses increases the DC fault current component time constant to values in excess of the standard value, necessitating the use of higher-rated circuit breakers than normal. The issue is exacerbated by increased volumes of embedded generation, which also contribute to increased fault levels. However, our view is that the deliberate use of transformers with high load losses to counter this problem is not justifiable or in line with our sustainability strategy. We will therefore continue to strive to minimise transformer losses and are employing and investigating other methods to manage system fault levels.

2. A second impact of reduced system losses is the reduction in damping that is available to higher-frequency phenomena such as harmonics or switching transients. The implication is that harmonic resonances are more pronounced and that oscillating transients take longer to decay. At this time, we do not have evidence that this is an increasing problem. However, increased harmonic levels themselves lead to increased losses, e.g. in MSCDNs as explained above or due to losses caused by harmonic currents flowing in circuits and equipment. In the longer term, changes in load characteristics (e.g. due to the increasing use of power electronic equipment) will also have an impact on system harmonics. We continue to keep our harmonic modelling techniques under review and also rely increasingly on direct measurements to manage harmonic levels on our network.

7. CONCLUSION

We are committed to reducing losses on our network wherever and however it is economic and efficient to do so. As we continue to connect more renewable generation in Scotland we are working toward getting the most out of our existing assets and increasing the capacity of our network to accommodate this generation. At the same time, we are also aiming to improve the overall performance of our network. This includes careful consideration of losses and minimising these as far as possible in a way that balances capital investment, operational cost and environmental impact. We will continue to analyse, monitor and record losses to demonstrate how our decisions are helping to reduce losses and thereby serving our customers better.

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