Scottish & Southern Electricity Networks

TRANSMISSION

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SHE Transmission RIIO-T2 Transmission Losses Strategy

December 2019

Scottish Hydro Electric Transmission plc

About us

We are Scottish Hydro Electric Transmission (SHE Transmission), part of the SSE Group, responsible for the electricity transmission network in the north of Scotland. We operate under the name of Scottish and Southern Electricity Networks, together with our sister companies, Scottish Hydro Electric Power Distribution (SHEPD) and Southern Electric Power Distribution (SEPD), who operate the lower voltage distribution networks in the north of Scotland and central southern England.

As the Transmission Owner (TO) we maintain and invest in the high voltage 132kV, 275kV and 400kV electricity transmission network in the north of Scotland. Our network consists of underground cables, overhead lines on wooden poles and steel towers, and electricity substations, extending over a quarter of the UK's land mass crossing some of its most challenging terrain.

We power our communities by providing a safe and reliable supply of electricity. We do this by taking the electricity from generators and transporting it at high voltages over long distances through our transmission network for distribution to homes and businesses in villages, towns and cities.

Introduction

Through a legislative and regulatory framework and pursuant to our Transmission Licence, we are obligated to develop and maintain an economic system of electricity transmission. This is important in order for us to enable the transition to a low carbon economy to achieve the optimum outcome for consumers and network stakeholders. One of the ways of achieving efficiency in transmission is to reduce the network losses. The impact of losses is factored into the cost benefit analysis during equipment procurement and when assessing solutions to system needs and undertaking strategic optioneering assessment, which presents an opportunity for us to make decisions that can reduce losses.

Power losses are an inevitable consequence of generating, transmitting and distributing electricity to consumers. In general, there are two main components of losses in a transmission system: technical losses and non-technical losses. Technical losses are energy lost as heat from power flows though electrical equipment such as cables, overhead lines, and transformers, while non-technical losses are caused by inaccurate metering, billing and energy theft.

Technical losses are the subject of this strategy and these are further categorised into fixed and variable losses, also known as no-load losses and load losses respectively.

- Fixed losses occur in a transmission system by virtue of it being energised and are independent of loading conditions. The fixed losses include corona losses in overhead lines and iron losses in transformers.
- Variable losses occur due to the loading of the transmission system this is dependent on the amount of load and can increase disproportionately with increasing load. The variable losses are heating losses due to the flow of electric current through the resistance of electrical circuits, such as the overhead line and cable conductors and transformer windings.

The power losses on GB transmission network is typically 2% of electricity generated. In 2017/18, the National Grid Electricity System Operator (ESO) determined that our transmission losses were 0.25TWh, which was 4% of total GB transmission losses. It could potentially supply 80,645 households assuming the 3100kWh electricity usage of a typical GB domestic household.

The Fig. 1 show the total energy and losses on distribution and transmission networks and how the transmission losses are split between the three transmission operators.

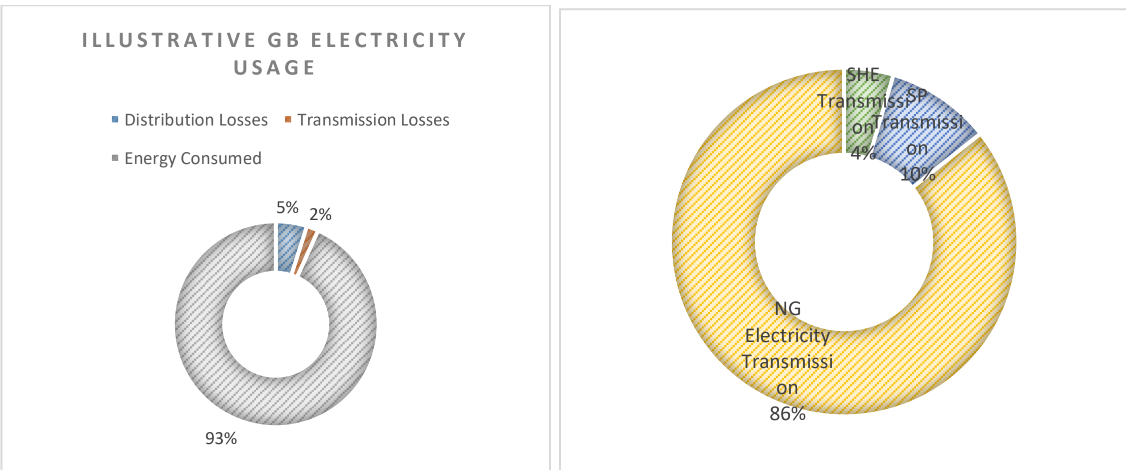

Fig. 1 Illustrative GB Electricity Usage

Fig. 2 shows the average annual losses in the last 10 years for our network is 0.31TWh, peaking at 0.38TWh in 2014/15 and with a minimum of 0.24TWh in 2010/11. Losses vary from year to year, however, there was a steady decline in transmission losses between 2013/14 and 2017/18. This period is when a number of major projects, such as Beauly-Denny 400kV overhead line and Crossaig-Hunterston 220kV subsea cables, have had an impact in reducing losses, by providing additional high voltage paths across the network and to the rest of Great Britain. Increasing volumes of generation on the distribution network during that period has also contributed to the decrease in transmission losses. These embedded generators can supply local demand, which reduces load on the relatively high-loss 132kV circuits that connect many of our grid supply points (GSPs) where the distribution network is connected to the transmission network. However, as more generators connect to the distribution network, generation may exceed local demand, and the excess power is exported from the GSP onto the transmission network which could increase transmission loading and losses.

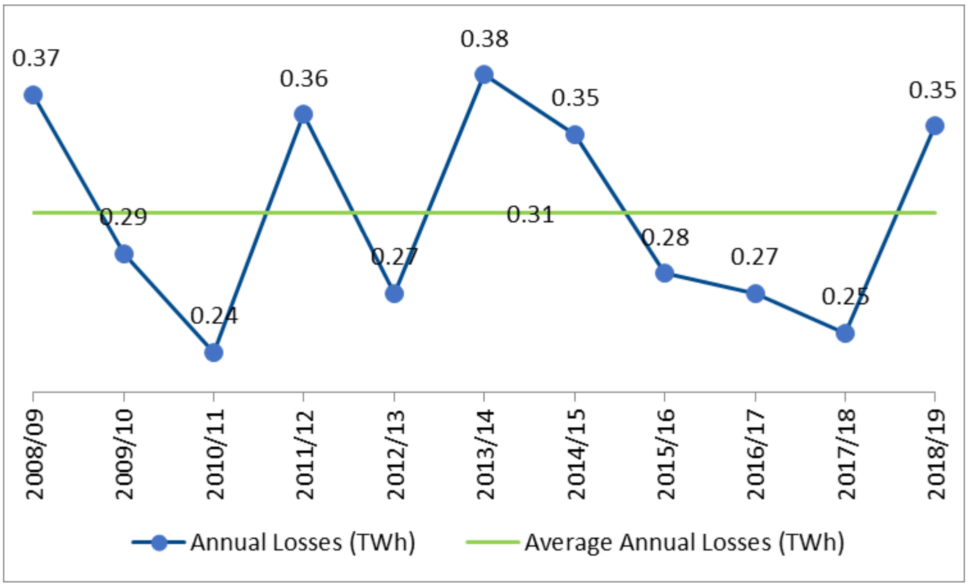

Fig. 2 Annual losses on the SHE Transmission system

In 2018, 1184MW of new renewable generation connected to our transmission system, including Beatrice and Stronelairg windfarms. The higher utilisation of transmission assets and renewable generation connections facilitated by the “Connect and Manage” regime has led to a reversal in the recent trend of declining losses, with a 0.1 TWh increase in 2018/19 compared to 2017/18. This has been corroborated by our analysis for the Electricity Ten Year Statement: the 2018/19 SHE Transmission MW losses under the average cold spell winter peak demand scenario are just under 40% higher compared to 2017/18.

Losses can be reduced through existing overhead line reconductoring, voltage upgrade, e.g. uprating from 132kV to 275kV operation, use of Flexible AC Transmission systems, HVDC technology and use of low-loss transformers. For the 120MVA 132/33kV GSP transformers, the losses of the most efficient one are 23kW (no-load) and 103kW (load), compared to a high losses transformer with 29kW (no-load) and 163kW (load), potentially saving 30% in terms of losses. While every measure is taken to minimise transmission losses, there are still a number of factors which must be considered when making investment decisions, and not all of these result in a reduction of transmission losses. These factors include capacity requirements to accommodate higher load requirements and the need to increase efficiency through maximising asset utilisation.

During the development of our RIIO-T2 losses strategy, SHE Transmission has also held many stakeholder engagement sessions, both internally and externally, including a special engagement event with round-table discussions and webinars in September 2019. We have managed to successfully engage more than 17 stakeholders representing 13 relevant organisations. This has given us the opportunity to not only present our losses strategy, but also to listen carefully to their views and feedback on our proposals.

This paper presents our approach in RIIO-T2 to be more proactive, going beyond our RIIO T1 activities in order to minimise the level of transmission losses and the associated Scope 3 indirect carbon emissions on our system. This supports our RIIO-T2 sustainability ambitions – mitigating climate change while connecting for society with a science-based target.

Methodology

Power losses on our network are mainly determined by the overall power dispatch. However, as a Transmission Owner (TO), we do not dispatch generation and demand on the transmission system – this is mainly driven by electricity market activity, with system balancing being a responsibility of ESO under its licence. We have very little opportunity in system operation to reduce losses. Approximately 98% of energy is traded on the electricity market and the ESO intervenes in the dispatch of remaining 2% of energy via their System Operator's role. It is also ESO's role to calculate annual losses for each TO area and we only review the calculations to understand the loss performance of our network and evaluate the impact of our network development activities on the losses. Due to above reasons, it is critical that we focus on our role in the specification of assets we install on our network to ensure that we take into account their lifetime losses impact and cost. We also consider the losses impact of the design options we develop in reinforcing the system.

> *"Energy losses are a huge consideration during the design process."*
> – **Supply Chain Representative**

Opportunities to reduce losses occur when there is need to replace an existing asset, driven by deteriorating asset condition or the need for more capacity, or when new assets are required to extend the transmission system. Due to the high capital cost of transmission assets, the losses reduction on its own generally does not yield an economic case for capital projects, but we recognise that it is important to include losses in our cost benefit analysis (CBA) when comparing alternative solutions for network reinforcement. We therefore consider the impact of losses when undertaking cost benefit analysis on procurement and reinforcement options to incorporate societal, economic and environmental factors.

Load and Non-load Related Reinforcement Projects

Power flow studies are used to determine the impact of the proposed load related reinforcement projects and non-load related asset replacement projects on transmission losses against generation background at system peak demand in the completion year of the project. Our studies are carried out against GB generation and demand backgrounds provided by the ESO, based on Future Energy Scenarios (FES), Electricity Ten Year Statement (ETYS), Grid Code "Week 24" submissions from the local Distribution Network Owner (Scottish Hydro Electric Power Distribution). The subsequent power flow studies for the transmission system planning and investment are applied to determine the transmission losses at cardinal loading points such as at the time of peak power flows on the transmission system, in order to estimate the annual losses and select the optimum design using the CBAs.

Quantifying Transmission Losses with whole system CBA

Traditionally, we mainly used the upfront Capex to determine the most economic option. Going forward, we will consider the whole system cost including the whole-life cycle estimated losses costs together with the maintenance and operation costs for the short-listed options following the conventional CBA.

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The subsequent power flow studies for the transmission system planning and investment are applied to determine the transmission losses at cardinal loading points such as at the time of peak power flows on the transmission system. The results can be used to project the reinforcement options' impacts on the system losses under the future energy scenarios, and to further estimate the annual losses and select the optimum design with a whole system CBA based approach.

> *"CBA across whole transmission planning to maximise impact of spending. This may mean targeting fewer 'big impact' projects rather than small gains on many projects."*
> **– Infrastructure Representative**

A new whole system CBA based approach allows the cost associated with network losses to be fairly balanced with other network costs. It can help to strike a balance between the total costs including losses, and constraint reduction and carbon savings. It also allows innovative smart grid technologies to be deployed on the network where the net benefits outweigh any increase in losses or in upfront capital investment. A full whole system lifecycle costing of investments will ensure that informed decisions are made before deploying any smart grid technologies and that network losses are fairly considered within any network investment.

We propose two elements associated with losses as inputs for the CBA:

1. cost of electricity production and transmission on our network; and
2. the traded carbon price associated with each tonne of CO_2 emission for the non-renewable portion of electricity energy in the north of Scotland.

This quantification of our losses cost (£/kWh) can then be used in our equipment procurement and investment option assessment to include the whole lifetime financial and environmental impact from losses.

The whole system CBA will play an important role in the reinforcement options assessment. A widely accepted and consistent methodology and procedures between ESO and three TOs are therefore essential to make sure the evaluation process is transparent and comparable when the CBA is running to determine the optimum solution among complex options involving various parties, e.g. in the Connection and Infrastructure Options Note (CION) and Network Options Assessment (NOA) process. In RIIO-T2, we will be working with other network operators and ESO to establish the methodology and procedures to consider the direct financial cost to consumers as well as the environmental impact.

Material and Equipment Specifications

The procurement of materials and equipment takes account of the whole lifetime costs including transmission losses. The losses will sit in hand-in-hand with the whole life cycle. In RIIO-T2, SHE Transmission will focus on the power transformers and conductors. The typical loading profiles for the different asset types, at all transmission voltage levels, will be provided to suppliers for use in the estimation of the whole lifetime fixed losses and various losses. It is important that, to ensure fairness in the tendering process, the methodology for determining the asset loading profiles and calculating the estimated losses are availed in a transparent manner. We will undertake the whole system CBA to determine the optimum selection of materials and equipment, considering the associated cost of losses described above in addition to other capital costs. Consideration is also given to the inclusion of post completion performance tests to provide confirmation that losses are accurate to loss values provided by suppliers in its tender.

> *"Transformers are a really good topic to discuss in this area because you're trying to look for something which is efficient and falls within your ambitions. I would be in favour of spending more."*
>
> – **Supply Chain Representative**

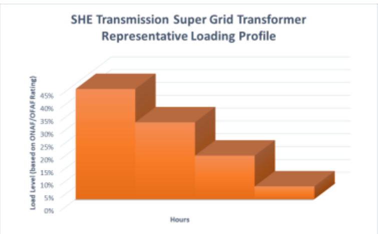
Opportunities to reduce both load and no-load losses occur when there is the need to replace an existing transformer, driven by deteriorating asset condition or the need for more capacity, or when new transformers are required to connect a new substation. The whole lifetime losses and associated carbon savings may alter our procurement decisions on the most economic power transformers. In the meantime, we are sending a clear message to the manufacturers that the GB society not only needs lower capital cost transformers, but also needs lower losses transformers to support the Net Zero ambition.

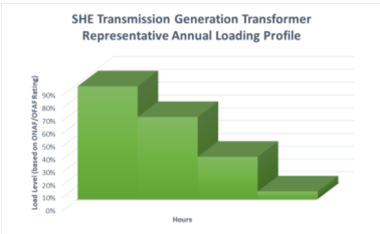
For the convenience of whole lifetime losses estimation, we categorise our power transformers into three types:

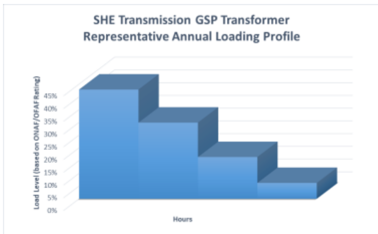
- **Grid Supply Point (GSP) transformers**: used to connect the demand and distributed generations at Scottish Hydro Electric Power Distribution's network.
- **Generation transformers**: used to connect the transmission directly connected generations, including the windfarms, hydro stations and solar parks and;

- **Super grid transformers**: used in our substations with an operating voltage higher than 132kV, for instance, key switching Main Interconnected Transmission System (MITS) substations.

We select various substations with both double and single transformer configurations across our network to produce the representative loading profile for the preceding three categories transformers. The transformers' representative annual loading profiles will be then used by our procurement team to consider the whole life cost of transformer losses and associated carbon emission in addition to the capital material cost of power transformers. The load level and associated duration from the representative loading profile are determined by the type of transformers. Manufacturers will be able to identify the no-load and load losses based on the information given. Using the latest average unit price of losses and average carbon conversion factors, the transformers' whole life cost of losses together with carbon footprint can be projected.







When replacing overhead conductors, an assessment of suitable replacements consistent with the capability of the existing tower structures is undertaken. Where appropriate, this can include a review of the conductor size versus cost and replacing conventional ACSR conductors with AAAC conductors or new technology conductors with a lower resistivity and associated losses. When selecting underground cables for asset replacement or reinforcement projects, consideration is taken on the type of conductor, dielectric material and sheath of the cable, in order to select cables offering optimum installation costs and losses.

"We look at losses when manufacturing products. We look at how they can be assembled in an eco-friendly environment"
– Supply Chain Representative

We will also request all the detailed relevant technical information to be provided for the material and equipment, which facilitates the future losses evaluation for comprehensive projects involving various assets and options. We will also proactively engage the manufacturer and supply chain stakeholders to optimise the design under the specific operating conditions in the north of Scotland, detailed in our Innovation Strategy.

Annual Reporting

We have a licence obligation to publish an annual transmission losses report for the previous financial year on or before 31 October in accordance with the Special Condition 2K of our licence conditions to monitor the transmission losses.

To provide a consistent and coordinated approach to the measurement and monitor of transmission losses for each TO, a joint methodology "Transmission Losses Calculation – Joint TO Methodology" was agreed between the respective TOs and the ESO to utilise the existing metering on the National

Electricity Transmission System and the apportionment of losses for each respective TO licensee's system. The ESO's calculation is carried out using data from the Elexon SAA-IO14 data feed, which allows each TO to report on their metered Transmission Losses as per the TOs Special Condition 2K.4. For the avoidance of doubt, the ESO is responsible for the accuracy of the annual transmission losses figures. Our focus is on modelled losses which are assessed against predefined generation and demand background.

In RIIO-T2, we are going to integrate the losses strategy requirements into the Business Plan environmental framework submission and integrate the annual losses reporting requirements into an annual environmental report as part of the environmental framework, as set out in the Section 3.86 in Ofgem's RIIO-2 Sector Specific Methodology Decision – Electricity Transmission.

We are also seeking a better way to enhance our losses data collection on the key components across our network. It will enable us to see how losses fluctuate all through the year as well as the contribution proportion from various assets. On top of that, we will endeavour to work more closely with the ESO and other two TOs on the losses data sharing and cooperation under the RIIO-T2 whole system collaboration framework, in order to fully take advantage of the data on the GB transmission losses.

Approach to New and Alternative Technologies

Our approach to new and alternative technologies is to apply solutions that prove new ways of working for the long-term benefit of our stakeholders and ourselves. Our stakeholder-led priorities within this approach are to maintain security of supply and to keep costs to a minimum. In order to do this as well as reduce the environmental impact of our activities, we are pursuing opportunities to reduce losses through new technologies and collaborations with our supply chain partners.

A good example is a recent trial at Tealing 275kV substation, collaborating with Edinburgh Napier University to reduce the electricity usage (transmission losses) at substations in terms of heating and lightning. The study shows the annual losses at Tealing 275kV substation is 192MWh/year. The proposed intervention measures include intelligent lighting controls and luminaire replacement and a range of building fabric upgrades to mitigate the electricity usage on site. The estimated losses saving can be up to 109MWh/year. It shows that readily available intervention measures can achieve savings of up to 41MWh/year per building on average which, extrapolated across our network portfolio, could amount to potential losses reductions 2GWh/year. It also highlights an opportunity to adopt onsite generation (e.g. solar panel) to cut the losses at substations. This improvement for the substation electricity usage has now been included in our RIIO-T2 plan to bring long term benefit for the customer in terms of losses and carbon cost savings going forward.

We have also completed the assessment and trial installation of an Aluminium Conductor Composite Core (ACCC) conductor on a 132kV wood pole transmission line. The design of the ACCC maximises the area of conductive material in the conductor, providing the same power-carrying capacity at a lower operating temperature than in conventional conductor designs. The lower comparative operating temperature leads to reduced losses, as well as a high current-carrying capacity that can defer or avoid the requirement for costlier conventional network reinforcement. With a typical resistivity of 106mΩ/mile for ACCC compared to 139mΩ/mile for ACSR, the losses using ACCC could be 24% smaller when carrying the same power flow. We are currently undertaking analysis of the trial results prior to potential transfer to business-as-usual practise in RIIO-T2. We will also continue to explore conductor opportunities in addition to the ACCC conductor which may offer further opportunities to reduce losses as well as increasing capacity. We will do this in line with the approach outlined in our Innovation Strategy.

We believe the set of new technologies described in this section highlight the need to reduce losses on our network and we remain committed to continuing to assess and deploy new technological solutions which deliver the greatest net benefit for the GB users and wider stakeholders.

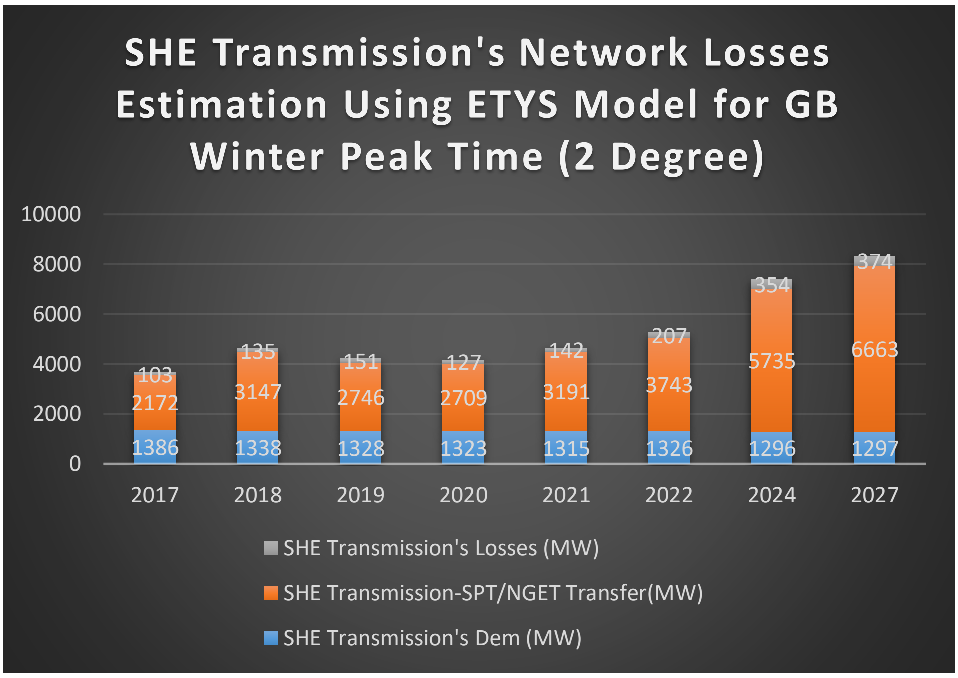
Impact of Future Developments on Scope 3 Transmission Losses

During the RIIO-T2 price control period, we are developing a number of key transmission reinforcement to accommodate the rapid growth in renewable generation in the north of Scotland. These developments include various conventional asset replacement and reinforcement works such as transformer replacements, new overhead lines and substations, re-insulation and re-profiling of existing overhead lines as well as High Voltage Direct Current (HVDC) technology, phase shifting transformers, power flow controllers and dynamic reactive compensation.

Figure 3 illustrates a forecast of the demand (in blue), power exports from north to south (in orange) and Scope 3 transmission losses (in grey) on our network at the time of GB winter peak demand time between 2017 and 2027 based on the ETYS 2018 model under the '2 Degrees' future energy scenario. The total of demand, exports and losses represents the generation output at the time of winter peak.

While all of the above developments have a beneficial impact on Scope 3 transmission losses, the rapidly increasing expansion of renewable generation in our area at both Transmission and Distribution levels (3661MW in 2017 vs an anticipated 8314MW in 2027) and resulting power exports through the network, means that overall losses will inevitably increase over time (103MW in 2017 vs an anticipated 374MW in 2027). The increase of absolute losses suggests we must focus on losses that we can influence through implementation of this strategy giving sufficient consideration of losses in equipment selection and network development options. As higher network losses can reflect higher network utilisation, the increase of losses is not, therefore, always a bad thing. It can be the result of increased renewable generation connection by way of, for example, various innovative Active Network Management (ANM) schemes.

In the meantime, the percentage ratio of losses over generation levels on our network is quite stable (3% - 4%) out to 2027, which reflects how our reinforcement development and efforts in losses reduction are effective. Subject to the increasing volume of renewable generation, the corresponding relative contribution from electricity losses to the carbon footprint could drop as well.



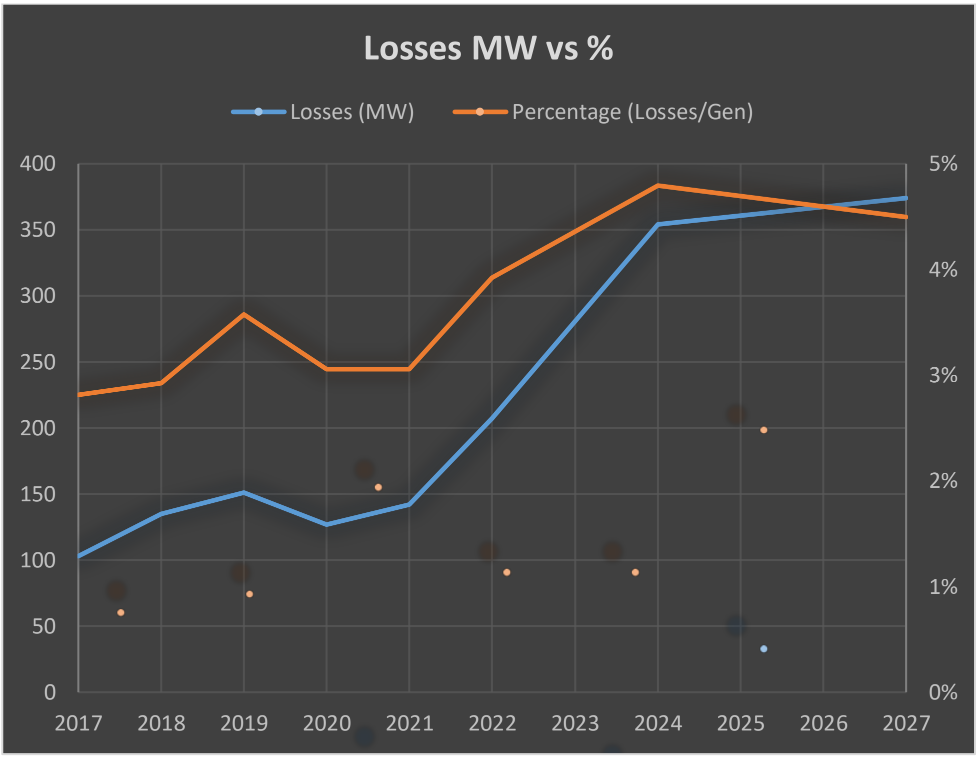


Fig.3 SHE Transmission's Network Losses Estimation Using ETYS Model for GB Winter Peak Time (2 Degree)

Stakeholder Engagement

As summarised in our September 2019 stakeholder workshop feedback report, 75% of stakeholders strongly agreed or agreed that the proposed strategy and action for transmission losses was appropriate. Stakeholders wanted us to start engaging with contractors who could provide solutions around costs and timeframes, and suggested we need to find a way to quantify and value losses for contractors. Just over half of stakeholders (55%) were neutral that the approach of spending more to control carbon towards the 2050 ambition would be justified, even though quantified CBA tells different results. The remaining 45% agreed or strongly agreed; with those that agreed advocating it would achieve the ambition that our strategy aims at. This is to help contribute to Net Zero by reducing losses. Some stakeholders admitted they do not consider energy losses when designing products as it is not mandated by clients. Others said they mainly focused on packaging and manufacturing when it came to lowering energy losses. As part of its strategy for minimising transmission losses it was suggested that we also look at: reducing flexi control and fibre cables; more digital substations; retrofitting inefficient transformer cores; driving through more HDVC interconnectors; highlighting the consideration at tender submission.

Going forward, we will continue to host effective, two-way engagement events to ensure that our losses strategy supports our customers' needs, meets the expectation of our stakeholders and is properly communicated and understood.

Summary

Our losses strategy is built upon our sustainability strategy which looks to enable the transition to a low carbon economy to achieve the optimum outcome for customers. We will proactively adopt the whole system CBA approach to make sure losses are minimised where possible to ensure costs to the GB consumer is minimised and to reduce the associated environmental impact (carbon footprint), as we committed to be the trusted partners of customers and communities, realising long-term benefit for society, economy and the environment.

During the RIIO-T2 price control period, we are proposing a number of transmission developments to accommodate the rapid growth in renewable generation in the north of Scotland, critical to the transition to a lower carbon economy and the government's Carbon reduction targets. These developments include various conventional reinforcement works, such as new overhead lines and substations, re-insulation and re-profiling of existing overhead lines, new HVDC links as well as substation energy usage improvement.

Over the short term, while all above have a beneficial impact on transmission losses, the rapidly increasing renewable power generation through the network could still mean that our overall losses remain flat or increase. Our transmission losses over the longer term, however, would decarbonise with the wider electricity network Net Zero pathway.

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We want to hear from you

If you have any questions or would like to provide any comments on this document and the information within it, please contact:

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