nationalgridESO

Year-round probabilistic thermal analysis

2019

Executive summary

We're experiencing an energy revolution. The economic landscape, developments in technology and consumer behaviour are changing at an unprecedented rate – creating more opportunities than ever for our industry.

I'd like to thank you for your valuable input to our *Network Development Roadmap* consultation published in early May 2018. Your views, knowledge and insight have helped shape this publication. Now we're able to show how we're developing our year-round probabilistic thermal analysis methodology to drive greater value for consumers. Having chosen part of the south-east coast of England for our analysis, we've drawn out some important messages.

We're now able to identify several network transmission needs, and to quantify the likelihood of events leading to transmission system thermal network stresses during the year. These needs have been identified using the 2018 future energy scenarios described by large quantities of wind generation and interconnectors in the south-east of England. This represents a step forward from our planning methodology that has traditionally been carried out against single snapshot "worst-case" scenarios, at winter peak demand – which comparatively identifies fewer network needs.

We've validated aspects of our probabilistic methodology and seen alignment with our current deterministic planning methodology. The limiting trips and overloaded circuits identified under both planning methodologies are the same. However, the probabilistic methodology further showed that these limiting trips and overloaded circuits appeared in other generation and demand conditions that were not identified by the deterministic methodology.

Furthermore, we're seeing that, compared to today, in a decade's time (based on the 2018 future energy scenarios) the transmission requirements in the south-east of England will become increasingly complex. However, we're able to deal with this complexity by using probabilistic techniques that cluster generation, demand and network background scenarios to pinpoint specific network thermal stress events. We've also seen that to solve these network stress events, we will need to encourage and assess a growing and diverse range of solutions beyond those currently considered through our deterministic approach – this could include network or non-network solutions across transmission and distribution.

We're still developing our probabilistic tool and analysis to allow for the greater assessment of the Great Britain National Electricity Transmission System (NETS) thermal transmission needs during the year, covering a wide range of future energy scenarios. We seek your feedback to support the development of our probabilistic network planning tool and analysis – to continue ensuring that our transmission system is always fit for purpose, and developed across the whole of Great Britain in an efficient way. Following your feedback, we will publish our intended use of the probabilistic tool and analysis for year-round thermal analysis for 2019/20 in the *NOA* methodology in Q2 2019.

You can share your views with us at transmission.etys@nationalgrid.com. I hope that you find this document, along with our other System Operator publications, useful as a catalyst for wider debate and engagement.

Nicholas Harvey
Head of Networks
National Grid ESO

Contents

Executive summary 1

Introduction 3

Probabilistic planning tool and analysis methodology 5

Case study 13

The way forward 36

1

Introduction

In line with our *Network Development Roadmap* consultation, and the changing nature of the electricity system, we present the Electricity System Operator's (ESO's) network planning progress toward using probabilistic techniques to assess year-round thermal requirements on the electricity network.

Building on our ESO Network Development Roadmap

Our *Network Development Roadmap (NDR) consultation*[1] was published in early May 2018. This proposed how the Electricity System Operator (ESO) could develop our network planning tools – primarily the *Electricity Ten Year Statement (ETYS)*[2] and *Network Options Assessment (NOA)*[3]– to drive greater value for consumers. One of our proposals was to assess the year-round transmission network needs to greater extent through taking a probabilistic approach. We initially published our findings in our 2018 *ETYS*, and, having built on this, we present our latest results in this document.

The changing nature of the electricity system

The motivation for our work is driven by the changing nature of the electricity system. As such, our current practice of identifying network needs based on the traditionally assumed winter peak scenario is now proving inadequate in planning the transmission system. It is important to study network needs across the year as well. We believe this is best achieved through a probabilistic approach. Adopting a probabilistic approach supports our existing deterministic approach (currently published in the *ETYS*) and allows us to look at credible conditions leading to various transmission needs over the whole year. This will allow us to consider conditions that are foreseen to arise during a year of operation as set out within the Security and Quality of Supply Standard (SQSS), the document which details the industry standard methodology and criteria against which our network is planned.

Considering year-round conditions should help improve the value that the *ETYS* and *NOA* drive for consumers by providing more informative data and therefore helping ensure the right balance between operational and network investment solutions – this could mean an increase or decrease in the amount of network investment recommended, based on whichever is the better outcome for consumers.

Stakeholder engagement and consultation

We're keen to hear your views on what we share in this document. Your feedback will help us to continue developing our network analysis approach and to improve how we communicate the outcome of our work with you, our stakeholders. We intend to conduct webinars where we can give detailed presentations on the content shared in this document. Please do get in touch with us via **transmission.etys@nationalgrid.com**

The rest of this document discusses our probabilistic methodology, case study results and insights, and shares ideas for the way forward.

[1] https://www.nationalgrideso.com/insights/network-options-assessment-noa/network-development-roadmap
[2] https://www.nationalgrideso.com/insights/electricity-ten-year-statement-etys
[3] https://www.nationalgrideso.com/insights/network-options-assessment-noa

2

Probabilistic planning tool and analysis methodology

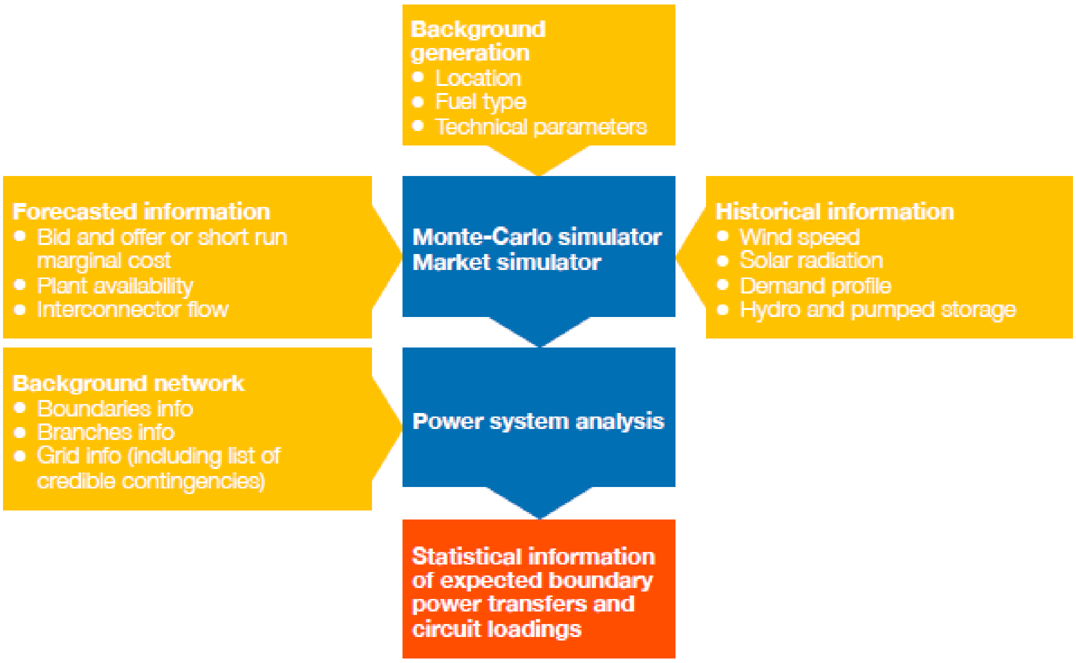
Our year-round probabilistic thermal assessment tool uses a combination of historical information about the electricity market, generation and demand, the future energy scenarios (FES) and the electricity network. This information is used via a Monte-Carlo algorithm to run year-round thermal network analysis to produce a range of network requirements.

Our probabilistic assessment tool

At the core of our probabilistic assessment tool is the Monte-Carlo algorithm which is used to generate many credible scenarios of generation and demand at any given time of the year. For each scenario, an economic dispatch algorithm is executed to find out what would be the output of available energy resources assuming an ideal electricity market. These market driven energy positions are used as inputs to compute DC power flow approximation – resulting in thermal loadings on the network.

The above process is repeated for many sample years. A given sample year will aim to capture all the hours in a year – this means every sample year will generate 8,760 sequential hourly scenarios. As the Monte-Carlo algorithm repeats the above process, and after generating many sample years, it produces data representing a range of thermal loadings both on individual transmission circuits and a group of circuits at a boundary level (described later in this chapter) – having considered the uncertainty of demand, generation and network topology. This process is summarised in the figure below.

Figure 2-1 Probabilistic thermal analysis diagram



Once the above-mentioned data are produced, data mining techniques can be used to extract and represent information statistically on what the network year-round thermal requirements are and what combination of generation, demand and network topology is driving these requirements. Furthermore, results such as hourly generation and demand snapshots which are subsequently evaluated by power system analysis can be used as supplemental data on which to perform further analysis and understand their impact on the network.

Probabilistic tool input data

The probabilistic tool uses both future energy scenario data and historical data. Future energy scenario data is used to model future generation and demand patterns and the historical data is used to dispatch the generation to match demand. The network development inputs we use to accomplish the process described earlier are summarised in the table below. The bold data are compatible with those we use in our *NOA* pan-European constraint costs assessment tool, BID3. BID3 is a market model optimiser tool focussed on analysing and establishing the benefits to consumers of different network reinforcement options. However, because our probabilistic tool is focussed on identifying network requirements, the data below are used differently from BID3. Nevertheless, we identify correlation and alignment between the two tools so that outputs from our probabilistic tool can be used as inputs to BID3.

Table 2-1 List of network development input data used in our probabilistic assessment tool

Network development input data			
Historical electricity prices for transmission connected generation of all types (except wind and solar)	**Historical hourly gross demand data**	Embedded generation data	Historical generator operational data for all generation types e.g. availability rates
Historical wind data to determine transmission connected wind dispatch	Network contingencies	**UK-Europe interconnector dispatch**	**Historical solar data to determine transmission connected solar dispatch**

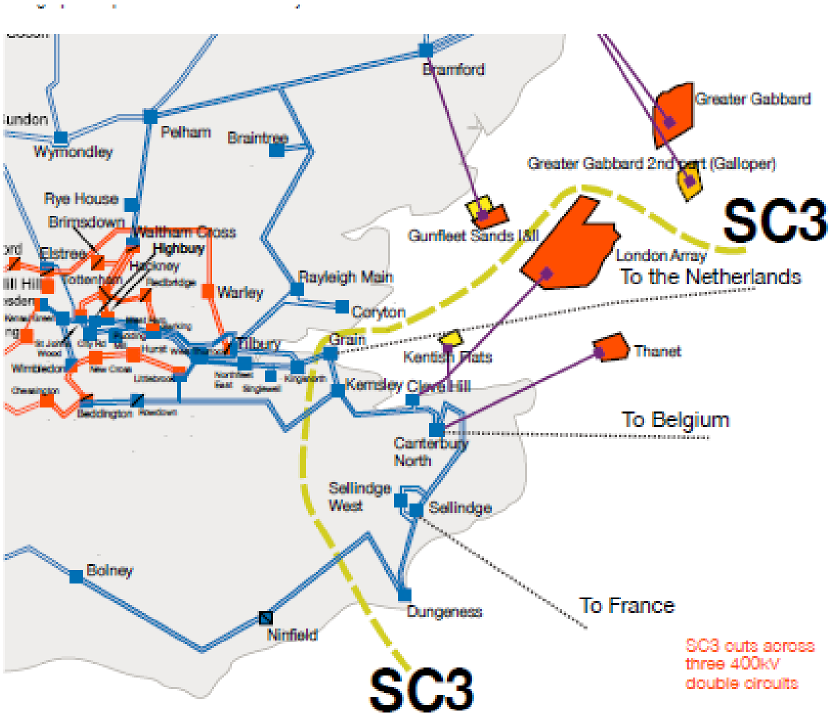
Integration of boundary-based system planning with probabilistic analysis

A boundary splits the transmission system into two parts, crossing critical circuit paths that carry power between the areas where power flow limitations may be encountered. In our deterministic network planning methodology, we use the concept of transmission boundaries to provide an overview of existing and future transmission requirements, and to report the restrictions we see on the transmission network.

Figure 2-2 shows an example of a boundary as a dotted line cutting across 6 circuits. Power can flow in either direction along these circuits. A boundary is constrained when the transfer of power is either limited by the total circuit capacity of these 6 circuits or the overloading of any circuit within about two substations distance of the boundary crossing circuits. It is unconstrained when the two above conditions are not met. When the boundary is unconstrained it means that power can flow in either direction through it.

The probabilistic analysis is compatible with the boundary approach. Using the example of Figure 2-2, for each generation, demand and network snapshot evaluated by power system analysis the total power flow across the 6 circuits will be summed to determine the boundary flow. This will be repeated for subsequent Monte-Carlo snapshots, and the overall boundary capability is assessed statistically after all the evaluated combinations of generation, demand and network topology have been considered as earlier discussed on page 6. Our proposed approach to calculating probabilistic boundary capability is discussed further on pages 8 and 9.

Figure 2-2 Example of a boundary region



Defining our boundaries has taken many years of operation and planning experience of the transmission system. Furthermore, we can use probabilistic techniques to analyse changes occurring on the network and to review whether existing boundaries are fit for purpose. In this way, we can justify removing, amending or defining a new boundary.

Probabilistic boundary capability assessment

Constraint forecast-error concept

In the 2018 *ETYS,* we suggested and described a method for processing statistical data about boundary flow into a single descriptive probabilistic boundary capability number – the constraint forecast-error method. In this report, we retain this method to describe probabilistic boundary capability as a single value which in turn allows us to compare our probabilistic results against the deterministic results.

Also, an updated concept – the dynamic constraint forecast-error concept – is introduced and used to deal with weaknesses in the constraint forecast-error concept in presenting some of the results in this publication, as discussed next.

Dynamic constraint forecast-error concept

The data needed to produce a probabilistic capability number based on the constraint forecast-error concept comes from two datasets; 1 the dataset of acceptable power flows across the boundary (i.e., flows which do not overload circuits within the boundary region under both intact and credible SQSS fault conditions and 2 the dataset of unacceptable power flows across the boundary (i.e., flows in which at least one circuit is overloaded within the boundary region under either intact or credible SQSS fault conditions.

When the values in these datasets overlap so much, it becomes difficult to represent the boundary capability as a single value. It then becomes necessary to use data mining and clustering techniques to make overlapping regions distinguishable enough to define a probabilistic capability number based on the constraint forecast-error concept.

It is dynamic because several probabilistic boundary capability numbers, rather than one capability number, of the boundary can be defined based on special clusters of power flow – which could be defined by criteria such as time of day or interconnector dispatch scenarios.

Representation and interpretation of results - example

Here, we present an example of how to interpret the results based on the constraint forecast-error we will later present.

We illustrate this in Figure 2-3, where we see seasonal plots. We can see that in each seasonal plot (winter, spring, summer or autumn) the unacceptable flows are plotted in orange and the acceptable flows are plotted in blue. While each of these plots gives us a good overview of the required flows across the boundary and the range of what can both acceptably and unacceptably flow across the boundary, there is a challenge in relying on these plots to derive a single boundary capability number through the constraint forecast-error concept earlier described. This problem is solved by converting these plots from showing MW to showing MWhr data. This transformation results in the plot shown in Figure 2-4.

To keep the interpretation of Figure 2-4 straightforward, the region of underestimated constraint volume is shaded in orange – to show that it is related to the unacceptable flow region in Figure 2-3. Likewise, the overestimated constraint volume is shaded blue to show that it is linked to the acceptable flow region of Figure 2-3.

The probabilistic boundary capability is calculated on the principle of balancing the risk of underestimating capability against that of overestimating capability. The former is the sum of lost opportunity in terms of the volume of energy transfer across the boundary [in MWhr/season] and the latter is the sum of the risk of transferring energy beyond what the boundary can do. In other words, opportunity volume is the MW transfer capability lost per hour because of underestimating the boundary capability, whereas risk volume is the MW transfer at risk of overloading the network per hour caused by overestimating the boundary capability. The point where the constraint forecast-error crosses zero is the identified boundary capability number – at this point the risk of overestimating or underestimating boundary capability is balanced.

Illustratively, we can see from Figure 2-3 that the acceptable and unacceptable regions overlap. The net effect of this overlap is that when it is translated from MW (Figure 2-3) to MWhr (Figure 2-4) it is possible to sum the two effects and realise a zero-crossing point which can be used to define the boundary capability as explained in the forecast-error constraint section. This zero-crossing point is clearly shown in Figure 2-4.

The zero-crossing results can then be summarised in a table to easily read and compare with deterministic results.

Figure 2-3 Acceptable and unacceptable boundary flow plots

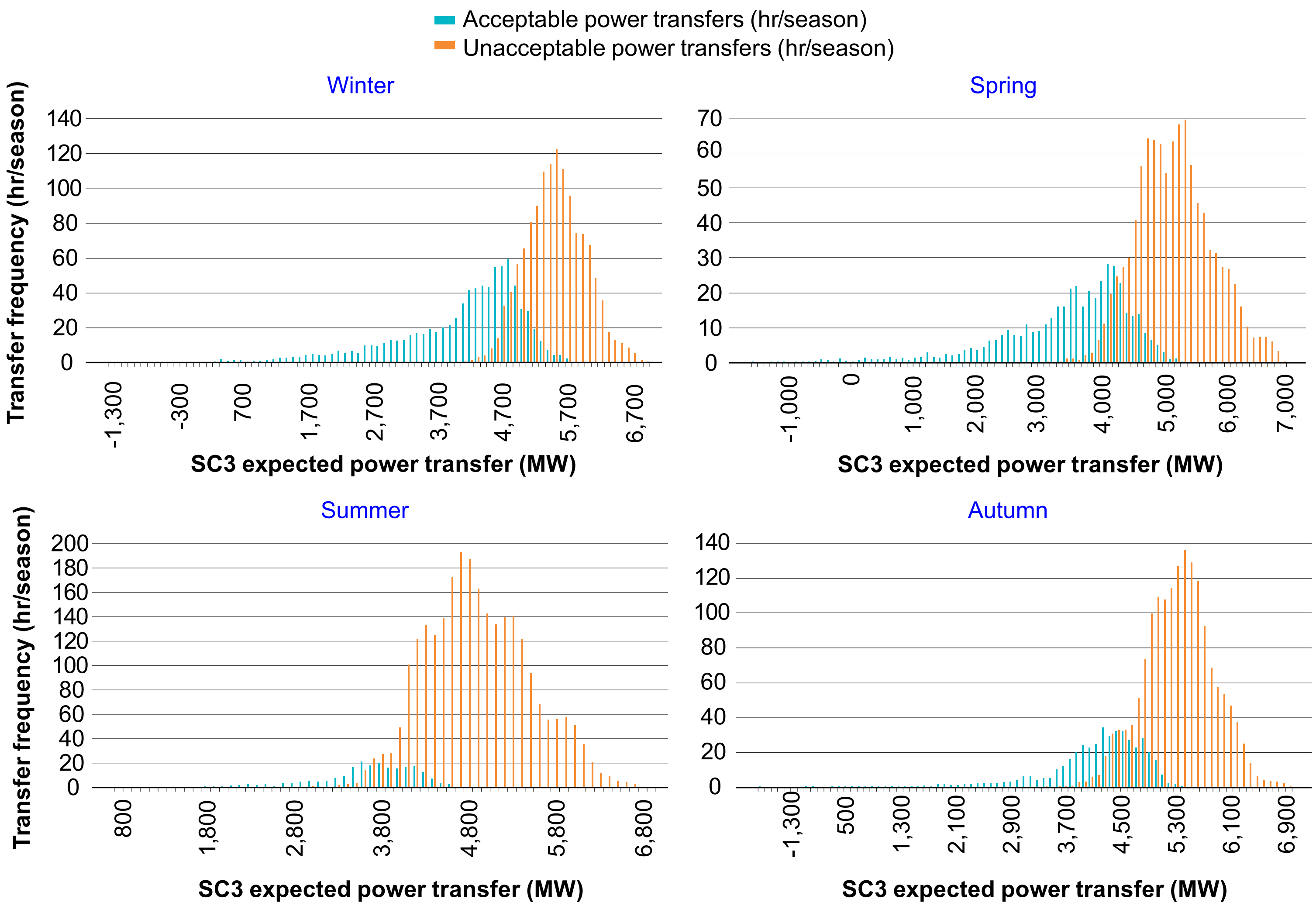
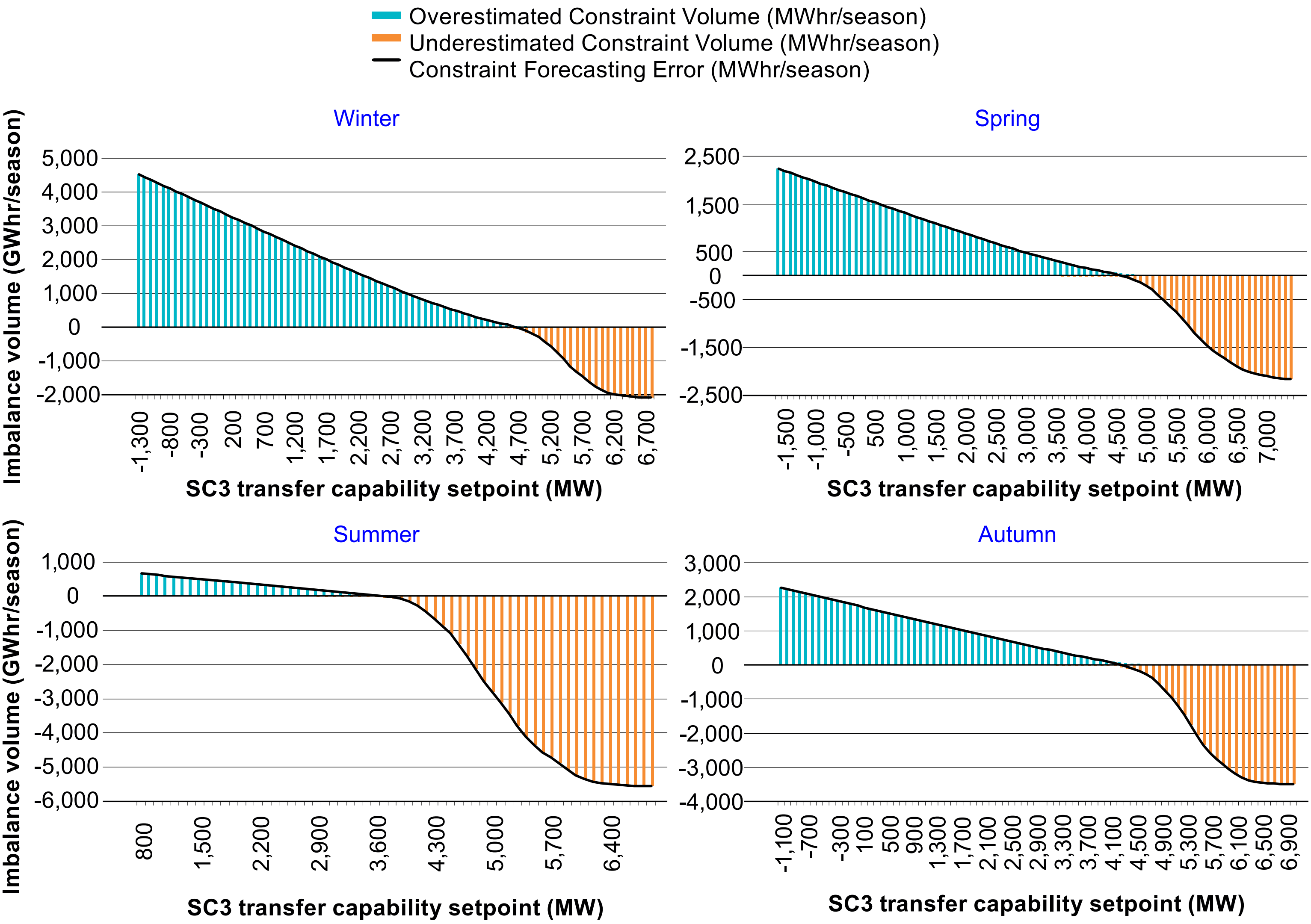


Figure 2-4 Constraint forecast-error probabilistic calculation plots



Further work and stakeholder feedback

While the results we present in this publication to showcase our probabilistic network planning methodology are based on the forecast-error constraint concept, we do acknowledge that other methods can be used.

We would like to know your thoughts on our proposed approach. Furthermore, we would like to know your thoughts on alternative approaches such as presenting only probability distributions or whether some other risk-based methods could be considered to enhance how we use our results to improve our planning process.

We welcome your views and engagement with us on how to best present and communicate probabilistic transmission network capability and requirements via transmission.etys@nationalgrid.com

3

Case study

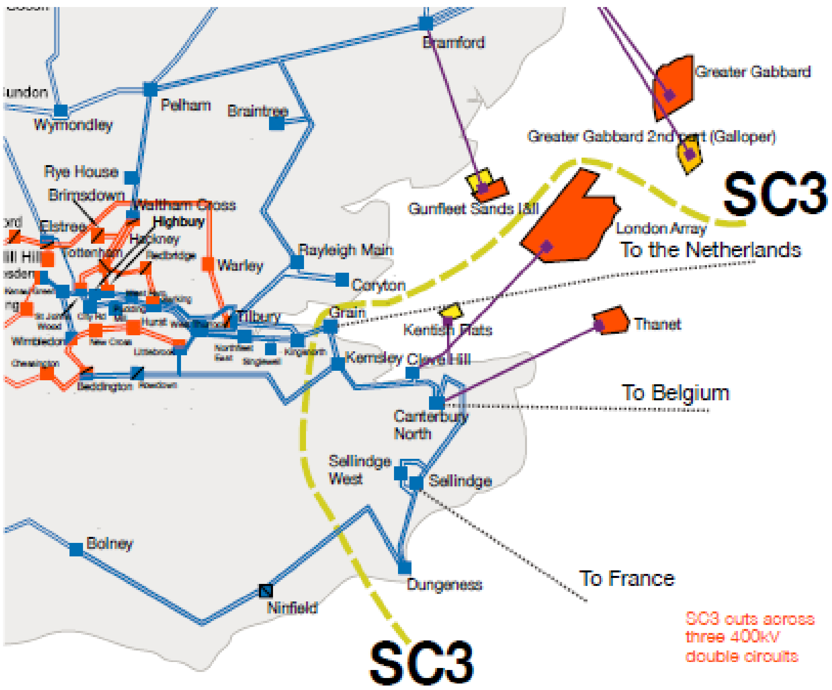
We've conducted a comparative assessment of the probabilistic year-round thermal analysis against the deterministic single snapshot. We show that the probabilistic approach complements the deterministic approach and can further identify a range of scenarios that could limit the capability of the electricity network, giving a fuller picture of transmission needs.

Selecting the transmission network

A lot of interconnector projects, especially from mainland Europe, are expected to connect to the National Electricity Transmission System (NETS). Interconnectors can both import and export power. This ability to be either demand or generation at different times is likely to place heavy transmission requirements in the region to which they connect.

We have chosen the south-east coast of England boundary (SC3) depicted below to understand the year-round thermal transmission capability needs that both the present and future interconnectors will place on the boundary. The current interconnectors to France, Netherlands and Belgium connect at Sellindge, Grain and Canterbury, respectively, with more expected to connect at various locations within the boundary in the future. Additionally, the targeted region covers a variety of energy resources such as nuclear generation and wind farms.

Figure 3-1 Geographic diagram of the SC3 boundary region



Defining the study methodology and deterministic comparative analysis

Our study methodology will perform year-round thermal analysis under the **Two Degrees** future energy scenario considering the following years: 2018/19, 2020/21, 2022/23 and 2027/28.

Using results from the probabilistic tool it is possible to see what extra information we can learn about transmission network needs in this region of the network across a given year and whether current network solutions can meet the system capability needs.

To illustrate the capabilities of the probabilistic tool, and get your views on the direction of its development, our results are focused on a single region of the GB network. Please note that our results should not be taken as a direct read across to the *NOA* results. This is because the *NOA* considers the impact of reinforcements from a GB-wide and not a single region perspective.

When we refer to *NOA* options we do so using them as a control to compare the differences we see in the results we get between the probabilistic and deterministic approaches to network planning. We do not use the full range of *NOA* options but consider just enough *NOA* options to allow us to illustrate the capability of our probabilistic tool and analysis methodology. This way we're able to get useful feedback from you – to help us develop our network planning process further – but still maintain customer confidentiality over that region of the network.

To compare our results with the deterministic approach, we have produced summary tables at the start of each study year section. Further results are presented in statistical form – descriptive of the probabilistic year-round thermal analysis simulations.

2018/19 – Two Degrees scenario

Table 3-1 Year-round probabilistic vs deterministic capability summary for 2018/19

	Probabilistic transfer capability, MW	Deterministic transfer capability, MW
Winter	4,750	**6,015**
Spring	4,150	**5,110**
Summer	3,750	**4,810**
Autumn	4,250	**5,110**

Summary results from the year-round probabilistic analysis are shown in Table 3-1 and compared with the deterministic single snapshot case.

The probabilistic transfer capability is calculated using data represented in Figure 3-2 which is converted to data represented in Figure 3-3. From Figure 3-3 the zero crossing number is taken as the probabilistic capability number for the season and updated in Table 3-1.

The deterministic transfer capability is calculated from the single snapshot case based on the winter peak demand and then appropriately scaled for the rest of the seasons.

The results in Table 3-1 show that the seasonal deterministic capabilities, being higher than the probabilistic capabilities, overestimate the level of power that can flow through SC3. The deterministic method fails to capture the variability associated with generation and demand. This makes the transmission network difficult to analyse and properly understand its transmission needs.

The identified limiting faults and thermal constraints using the deterministic approach aligned with those found through probabilistic techniques. However, from the statistical plot in Figure 3-4 we can further see that the power flow restrictions follow a probability distribution rather a deterministic output. Therefore, the probabilistic approach helps us enhance our analysis and provides more informative data relating to network requirements from a year-round perspective.

In this study no reinforcements were considered. Study years 2021/22 and 2022/23 and 2027/28 compares the deterministic with the probabilistic approaches considering both unreinforced and reinforced network conditions.

We welcome your views and engagement with us on how to best present and communicate probabilistic transmission network capability and requirements via transmission.etys@nationalgrid.com

Figure 3-2 Acceptable and unacceptable boundary flow plots for study year 2018/19

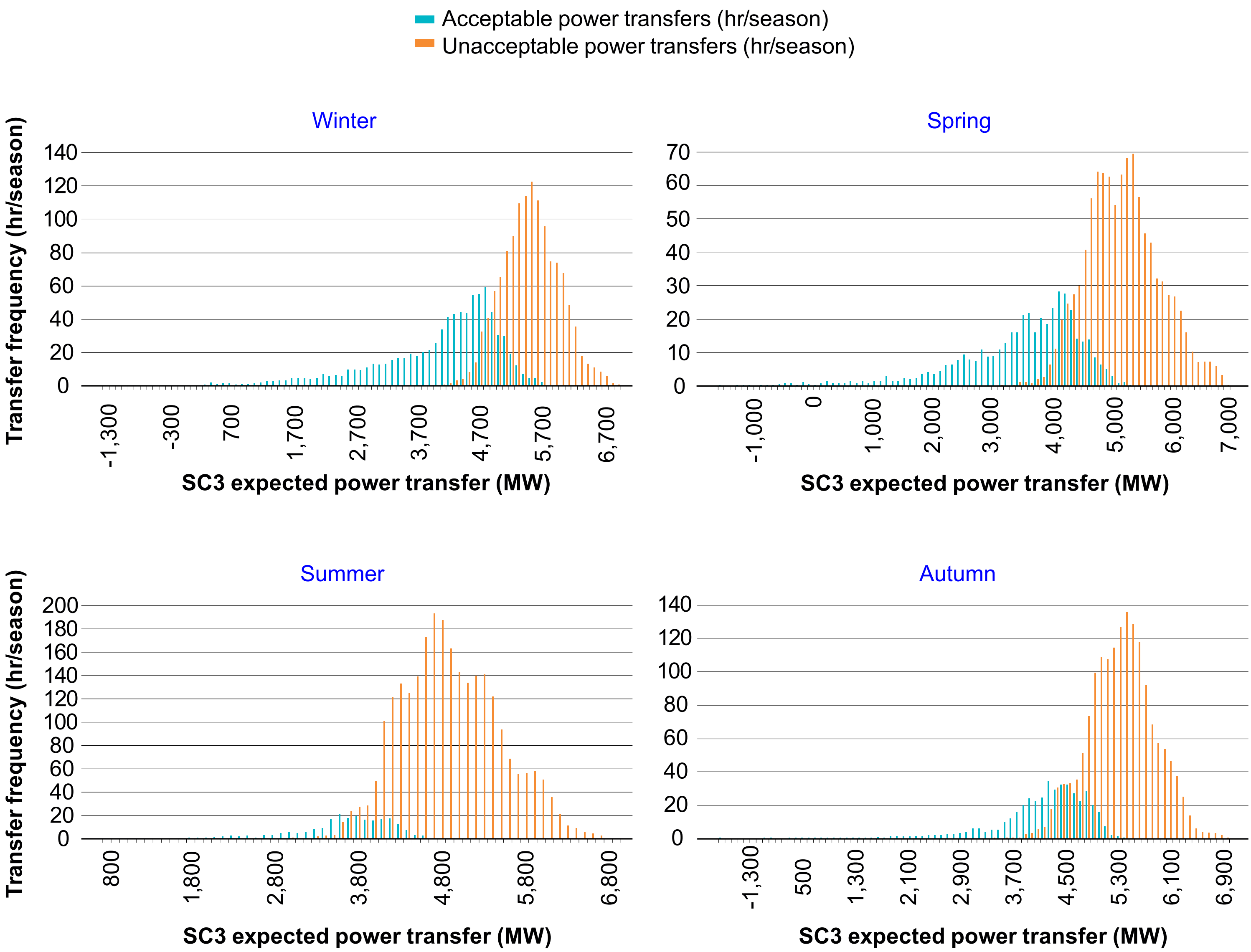
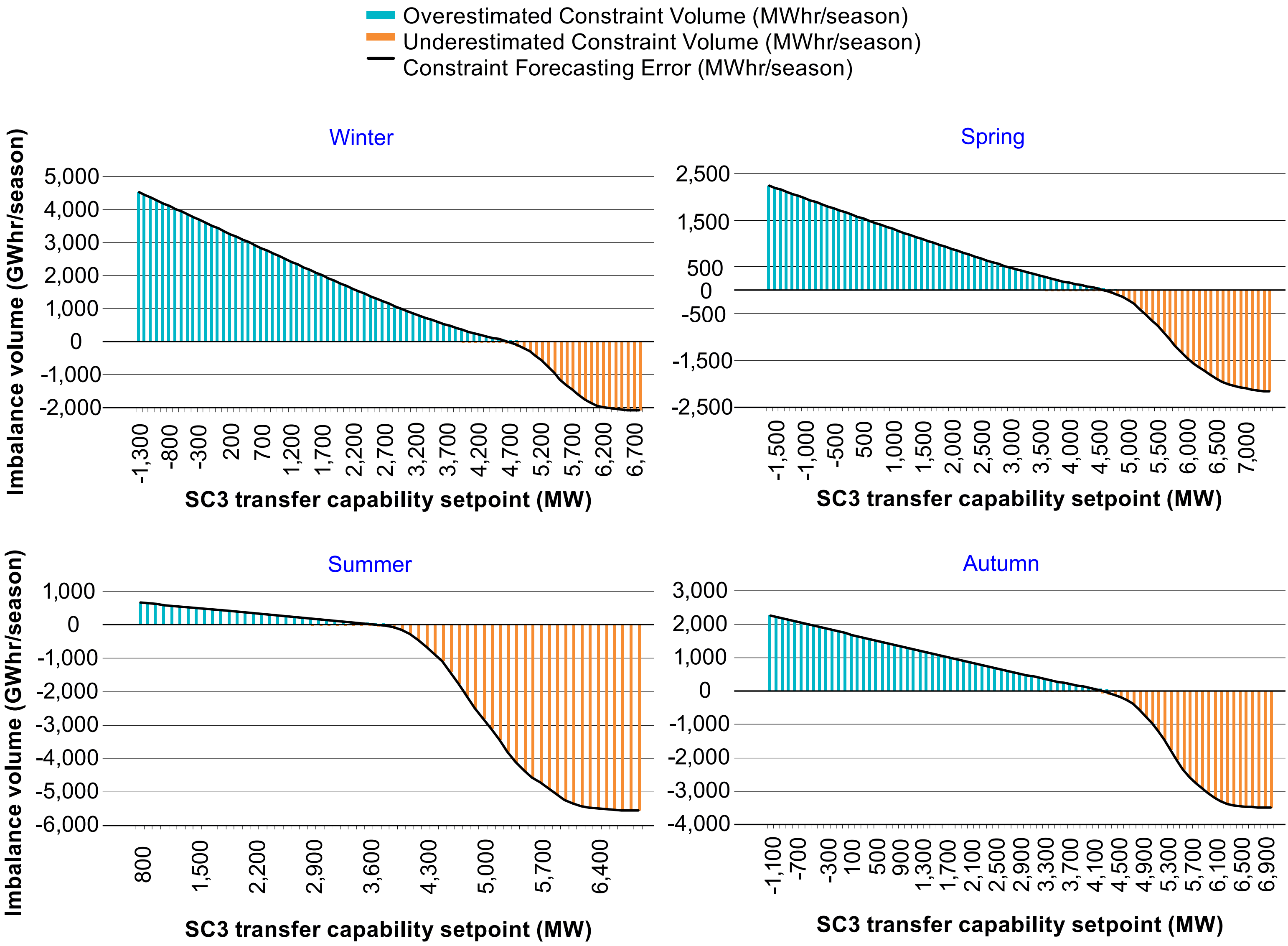


Figure 3-3 Constraint forecast-error probabilistic calculation plots for study year 2018/19



2020/21– Two Degrees scenario

Table 3-2 Year-round probabilistic vs deterministic capability summary for 2020/21

Season	Unreinforced network		Reinforced network	
	Probabilistic transfer capability, MW	Deterministic transfer capability, MW	Probabilistic transfer capability, MW	Deterministic transfer capability, MW
Winter	4,550	**5,700**	6,950	**7,600**
Spring	4,050	**4,850**	6,450	6,450
Summer	3,450	**4,550**	5,750	**6,100**
Autumn	4,250	**4,850**	**6,550**	6,450

In this study year, the generation mix within SC3 has become more diverse. The probabilistic capability numbers in Table 3-2 come from the zero crossings in Figure 3-5. The plots in Figure 3-5 are produced from the distributions in Figure 3-4.

The unreinforced network numbers in Table 3-2 are compared against capability requirements. For the unreinforced network, and under both the probabilistic and deterministic capabilities, the network does not meet system capability requirements – and will need to be reinforced. For this study, we have considered some of the relevant *NOA* reinforcement options.

After the relevant options are used to reinforce the network, the results of the reinforced network are shown in the relevant parts of Table 3-2 and Figures 3-4 and 3-5. Once again these results are compared with the system capability requirements. Considering the probabilistic results, the network does not meet capability requirements; although the deterministic values suggest that it does. As noticed in the earlier study the deterministic study will fail to capture the range of multiple background conditions. By accounting for more background conditions under the probabilistic methodology we see that additional reinforcements beyond those identified through the *NOA* process might be required, to meet transmission system requirements under conditions that might be reasonably expected during the year.

We welcome your views and engagement with us on how to best present and communicate probabilistic transmission network capability and requirements via transmission.etys@nationalgrid.com

Figure 3-4 Acceptable and unacceptable boundary flow plots for study year 2020/21

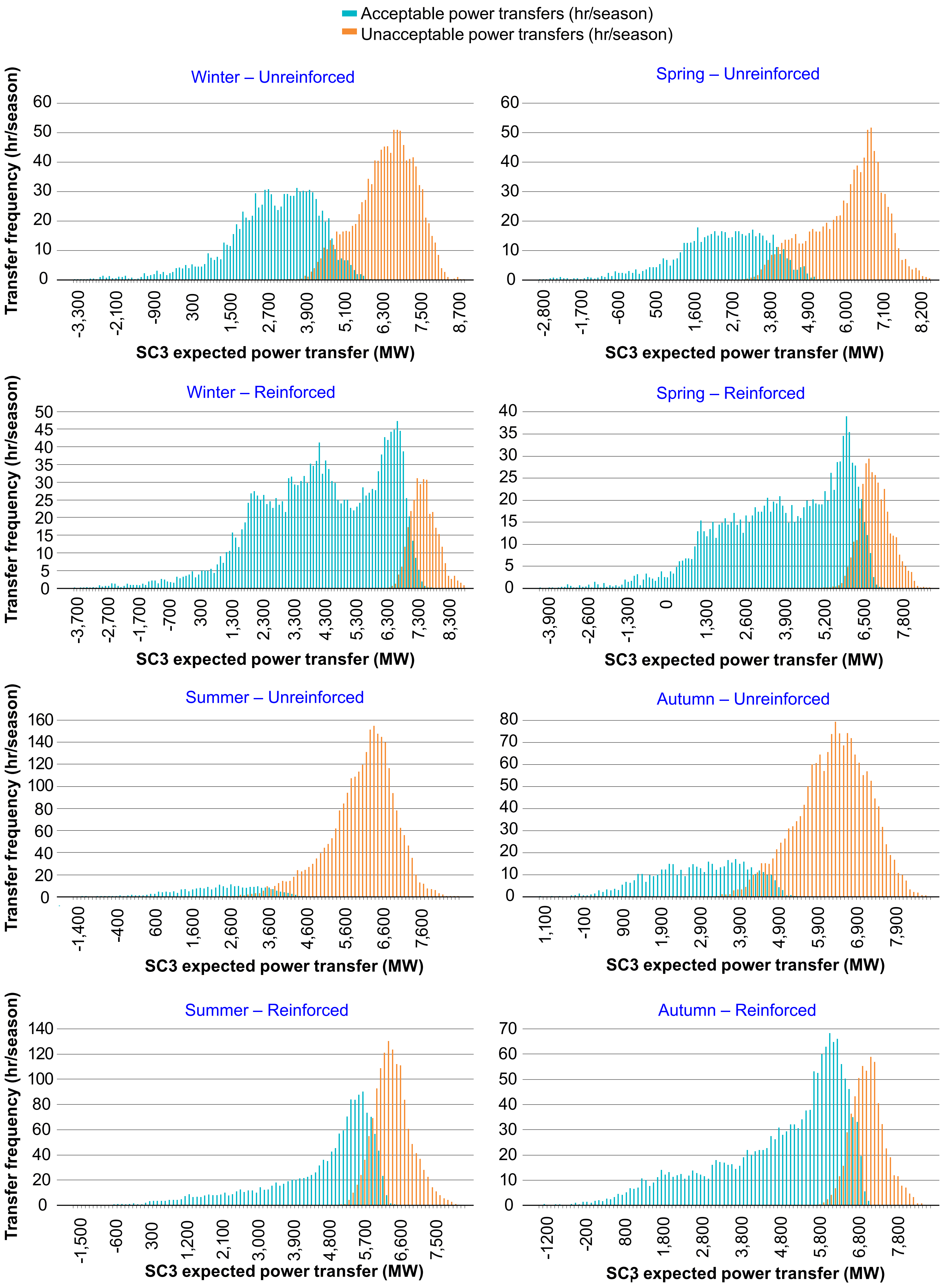
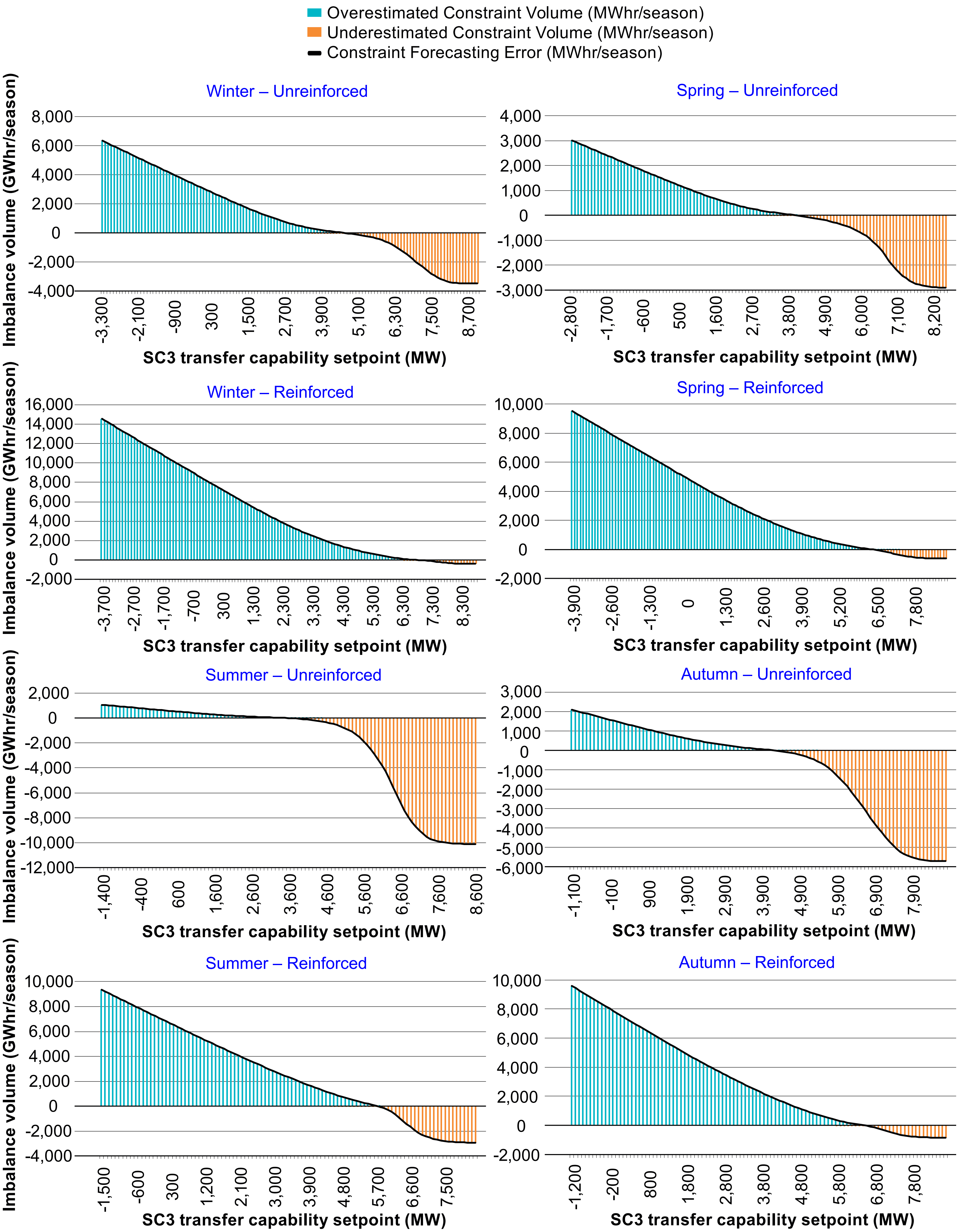


Figure 3-5 Constraint forecast-error probabilistic calculation plots study year 2020/21



2022/23 – Two Degrees scenario

Table 3-3 Year-round probabilistic vs deterministic capability summary for 2022/23

Season	Unreinforced network		Reinforced network	
	Probabilistic transfer capability, MW	Deterministic transfer capability, MW	Probabilistic transfer capability, MW	Deterministic transfer capability, MW
Winter	4,850	**6,255**	7,050	**7,280**
Spring	4,250	**5,315**	**6,650**	6,190
Summer	3,550	**5,005**	**5,850**	5,824
Autumn	4,350	**5,315**	**6,750**	6,190

In this study year, the generation mix has changed and this means that the region's uncertainty profile (from the perspective of generator prices, availability rates, interconnector dispatches, for example) has changed. This new uncertainty profile imposes different seasonal requirements from those witnessed in earlier study years. The summary of results is given in Table 3-3. The probabilistic results updated in Table 3-3 are zero crossing values derived from the data represented in Figures 3-6 and 3-7.

Both the deterministic and probabilistic results for the unreinforced network case result in a boundary that does not meet capability requirements. After the application of reinforcements both the probabilistic and deterministic capabilities meet transmission capability requirements. However, from Figure 3-6 we see that even after reinforcing the network, across all seasons there are several unacceptable boundary flow scenarios.

Our current deterministic planning methodology allows for the planning of a network beyond the minimum transmission requirements. However, it is difficult to justify doing so because of the challenge faced in determining reasonable background conditions. Using the probabilistic methodology it is possible to justify planning the network beyond minimum capability requirements because the use of probabilistic risk assessment techniques enables us to identify conditions that result in network constraints.

In summary, this study has demonstrated that our probabilistic assessment can capture and quantify the likelihood of the conditions that could arise during the course of a year leading to greater understanding of network requirements and consequent reinforcements ensuring that we meet the future network needs in the most economical and secure way.

We welcome your views and engagement with us on how to best present and communicate probabilistic transmission network capability and requirements via transmission.etys@nationalgrid.com

Figure 3-6 Acceptable and unacceptable boundary flow plots for study year 2022/23

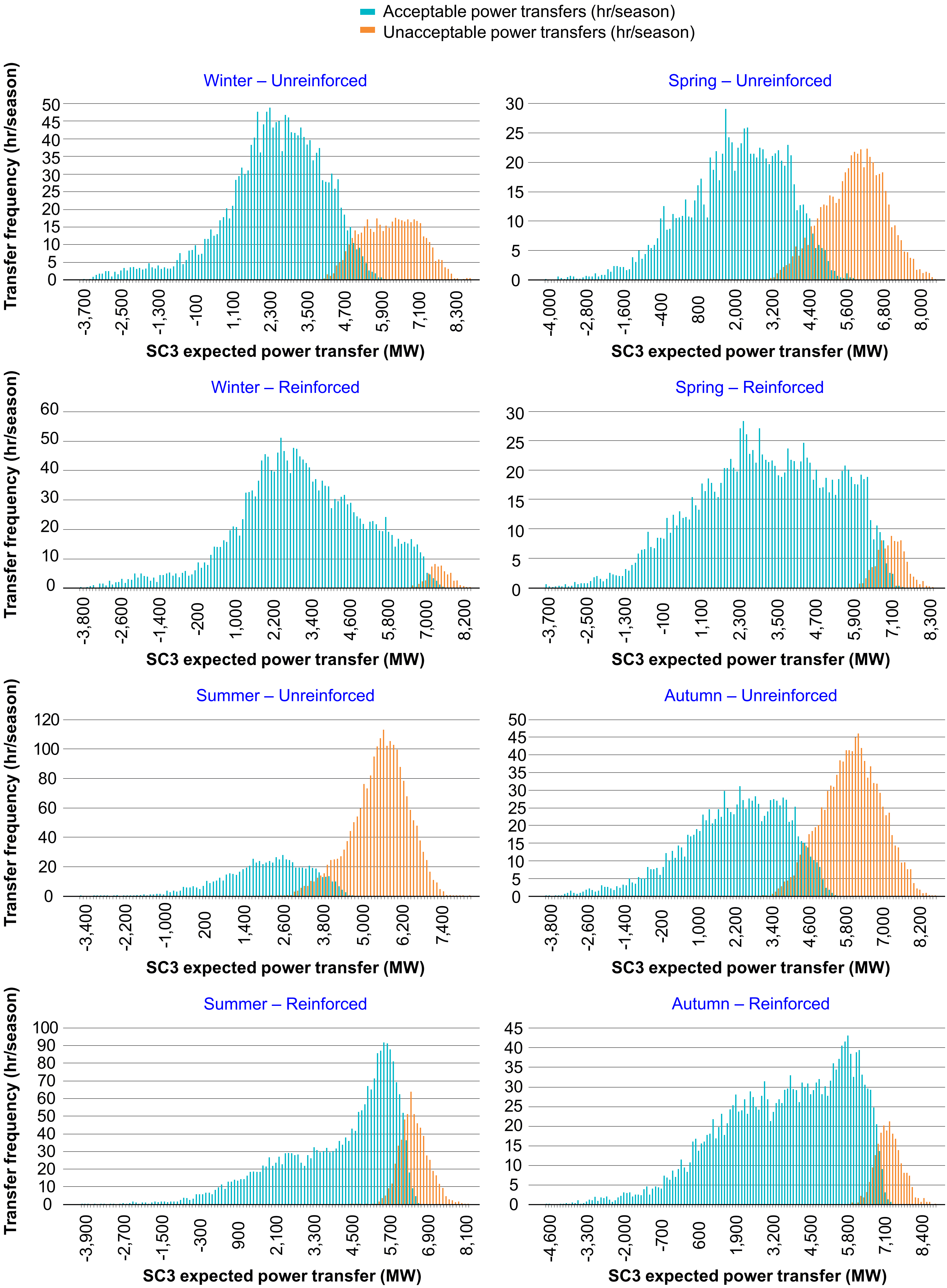
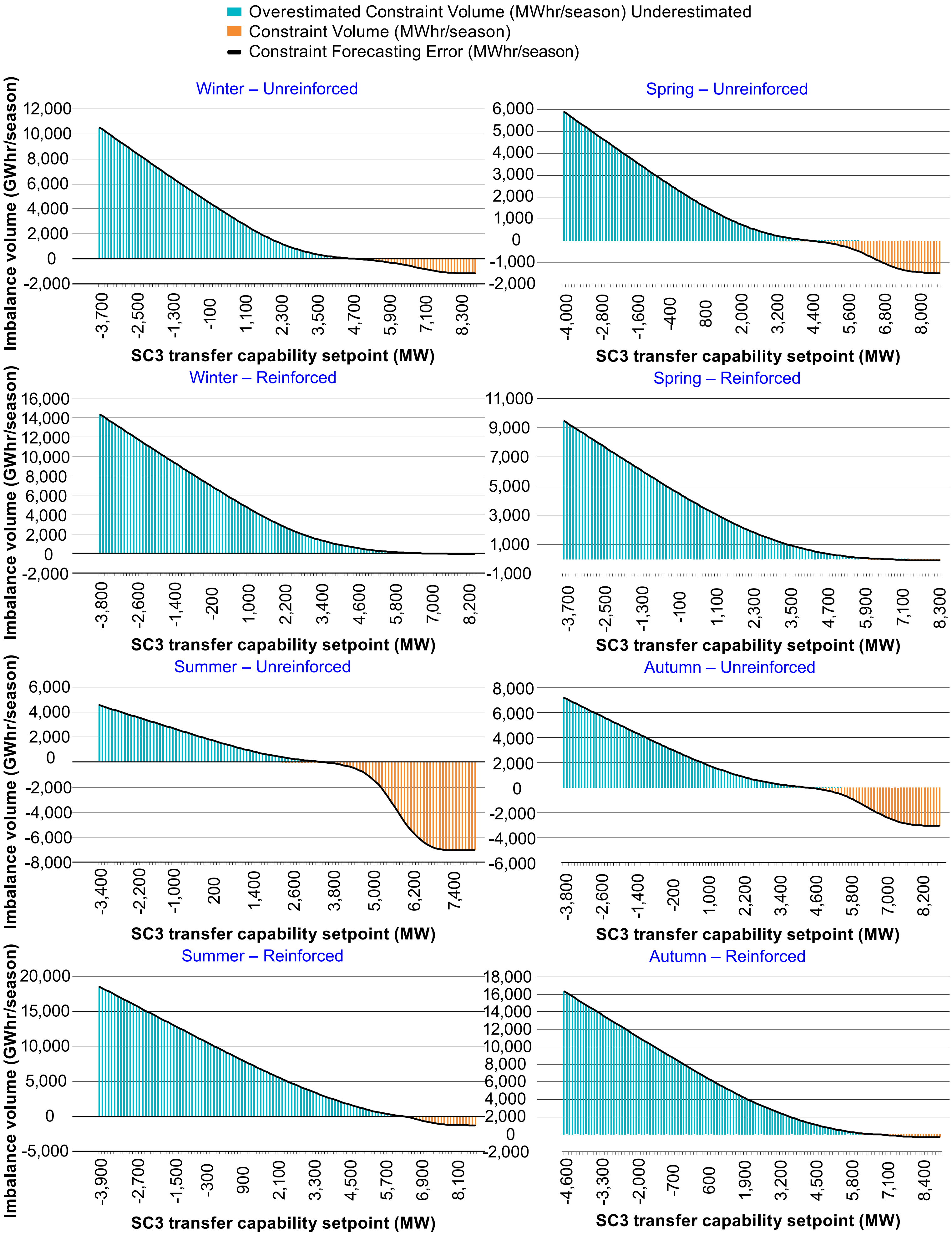


Figure 3-7 Constraint forecast-error probabilistic calculation plots study year 2020/21



2027/28 – Two Degrees scenario

In this study year, we see significant changes in generation and demand. Overall generation capacity, including interconnector capacity, is higher than previous study years – meaning that planning to meet year-round requirements by defining a probabilistic boundary capability per season will not satisfy all the conditions that could arise through the course of a year. In this section, we show how we use the statistical results from our study to identify a broader range of conditions and highlight the factors behind defining the dynamic probabilistic boundary capability. In this way, we show how probabilistic boundary capability can be defined dynamically to correspond to the likelihood of events on the transmission system throughout the year.

Figure 3-8 shows the plots of acceptable and unacceptable power flows for both the unreinforced and reinforced cases. We see that the degree of overlap between acceptable and unacceptable flows is much greater than that shown in previous similar plots. This illustrates how complex the network has become to operate in 2027/28, owing especially to interconnector activity changing between import and export and at times some interconnector groups importing against other interconnector groups exporting. As such it has become difficult to calculate a single probabilistic boundary capability number.

This problem has been solved by employing data mining techniques. This has helped us to understand what is going on with the network across the various scenarios. As such, from our analysis on this occasion, we notice that network constraints are largely driven by three interconnector scenarios – when all interconnectors in the boundary are exporting to Europe, when there is a group of interconnectors exporting versus another group importing and when all interconnectors are importing from Europe.

The boundary flow ranges between -6 GW and -3GW when all interconnectors in the boundary are exporting to Europe. When there is a group of interconnectors exporting versus another group importing the boundary flow ranges between -3GW and 4.5GW. The boundary flow is greater than 4.5 GW when all interconnectors are importing from Europe.

Given these three outcomes it is possible to define probabilistic boundary capability numbers that are driven by these scenarios and their consequent boundary power flow ranges using the forecast constraint-error within the respective ranges defined above. Therefore, three cases of dynamic capability results are presented.

Case 1 represents the boundary capability numbers calculated for the probability distribution representative of boundary flows greater than 4.5 GW, when all interconnectors are importing from Europe. Results are summarised in Table 3-4.

Case 2 represents the boundary capability numbers calculated for the probability distribution representative of boundary flows ranging between -3GW and 4.5GW, when there is a group of interconnectors exporting versus another group importing. Results are summarised in Tables 3-5.

Case 3 represents the boundary capability numbers calculated for the probability distribution representative of boundary flows ranging between -6 GW and -3GW when all interconnectors in the boundary are exporting to Europe. Results are summarised in Table 3-6.

Figure 3-8 Acceptable and unacceptable boundary flow plots for study year 2027/28

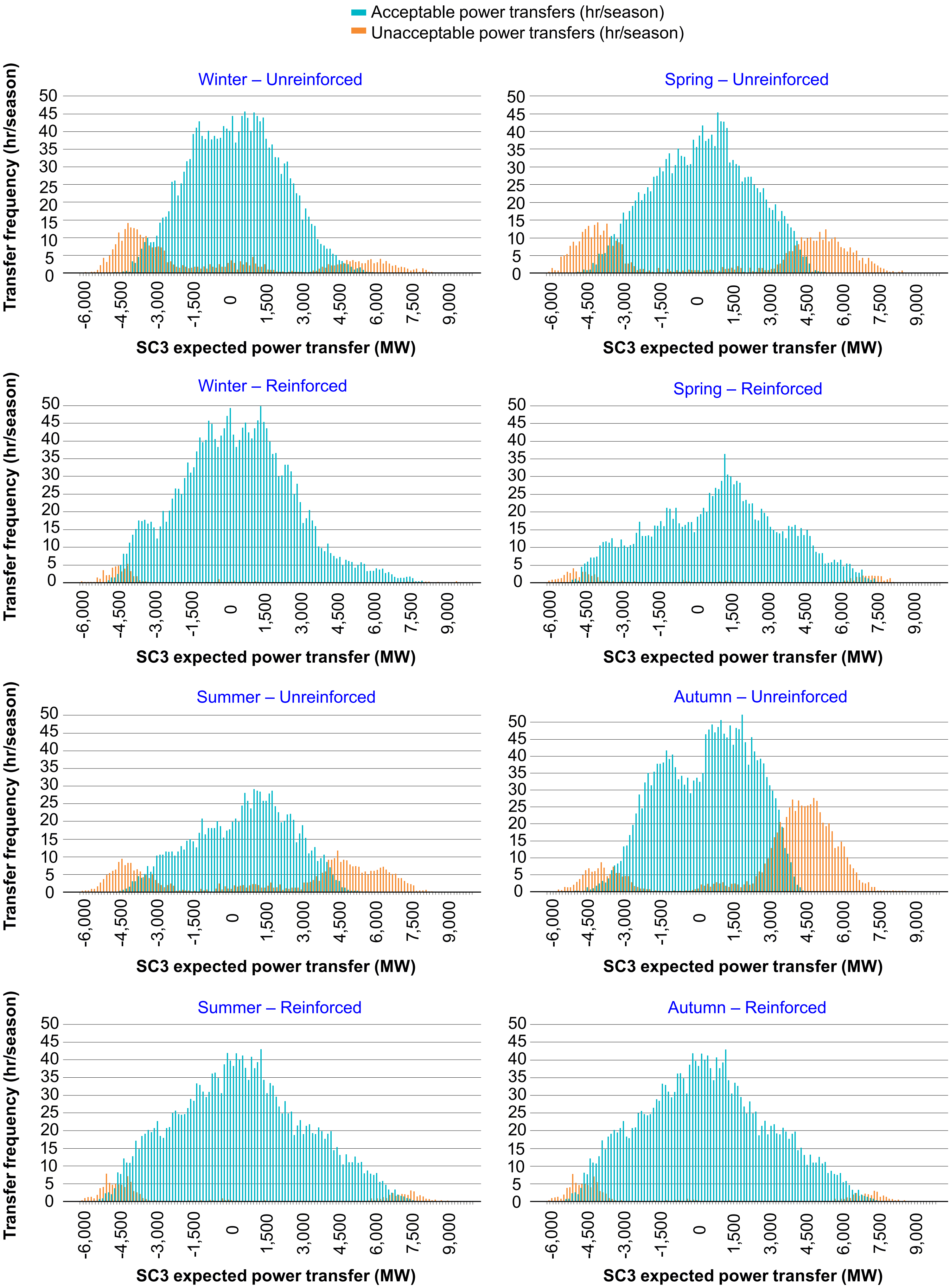


Table 3-4 Year-round probabilistic vs deterministic capability summary for 2027/28 – case 1

Season	Unreinforced network		Reinforced network	
	Probabilistic transfer capability, MW	Deterministic transfer capability, MW	Probabilistic transfer capability, MW	Deterministic transfer capability, MW
Winter	4,925	**6,800**	7,300	**9,800**
Spring	4,575	**5,440**	6,450	**7,840**
Summer	4,565	**5,780**	6,450	**8,330**
Autumn	4,450	**5,440**	6,550	**7,840**

In the table, the probabilistic capabilities are derived from Figures 3-9 and 3-10, whereas the deterministic capabilities are calculated assuming winter worst case demand and then scaling it for the rest of seasons.

Prior to reinforcing the network both deterministic and probabilistic capability numbers do not meet transmission capability requirements. After reinforcement, considering a selection of *NOA* reinforcements, only the deterministic capability numbers meet the minimum transmission requirements. However, the deterministic study fails to account for the full range of interconnector behavior and thus overestimates the capability of SC3.

The probabilistic analysis better deals with the interconnector characteristic of changing between generation and demand operating modes, and, as such, captures the scenarios that stress the network.

Moreover, as the probabilistic analysis captures the full range of interconnector activity, the limiting contingencies and overloaded circuits change. This is the reason we need to determine dynamic boundary capability aligned with interconnector activity, and failure to do so could result in grossly overestimated boundary capability and under estimated network requirements. Further results on this are shown in Tables 3-5 and 3-6.

We welcome your views and engagement with us on how to best present and communicate probabilistic transmission network capability and requirements via transmission.etys@nationalgrid.com

Figure 3-9 Acceptable and unacceptable boundary flow plots for study year 2027/28

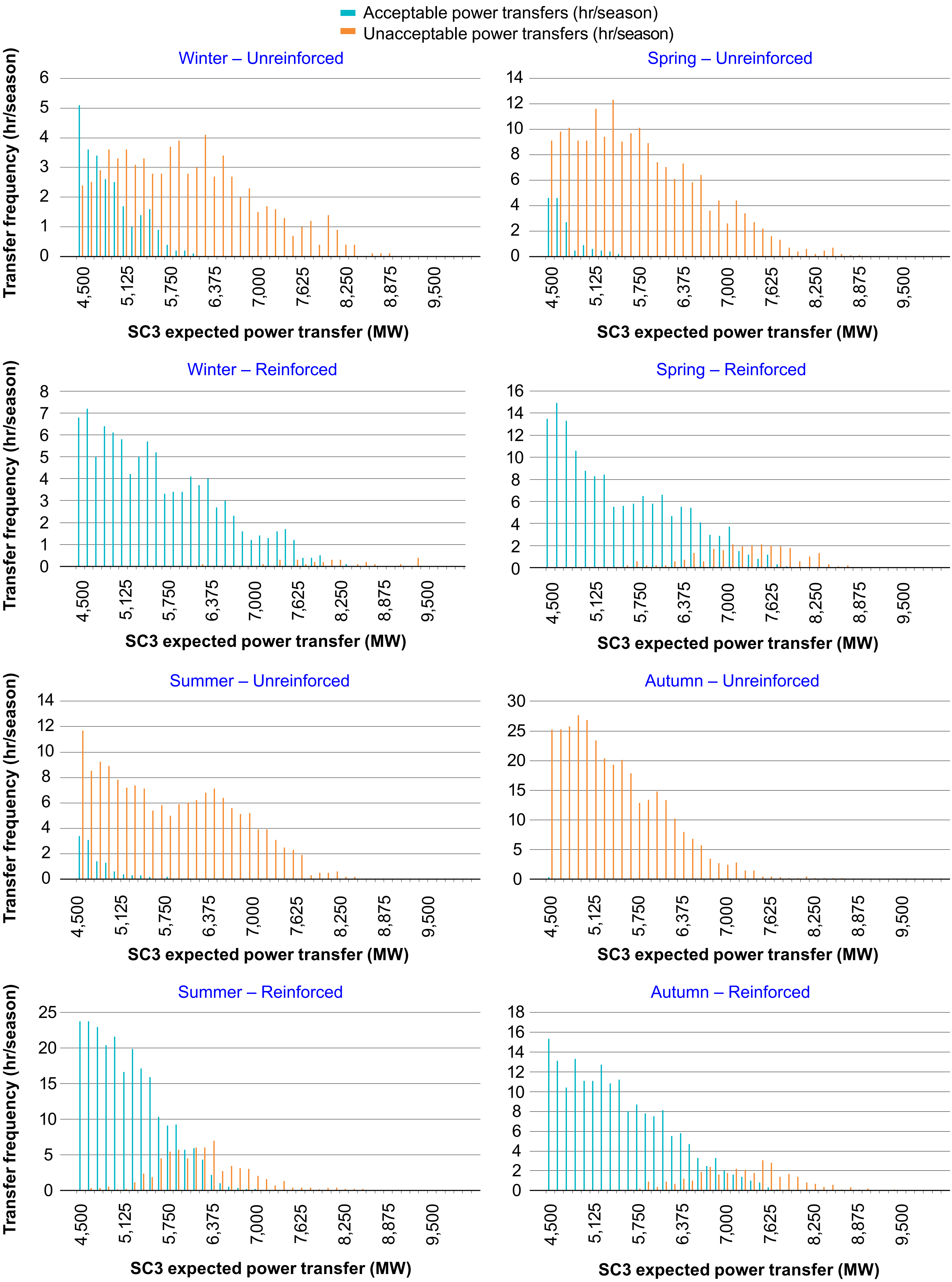


Figure 3-10 Constraint forecast-error probabilistic calculation plots for study year 2027/28

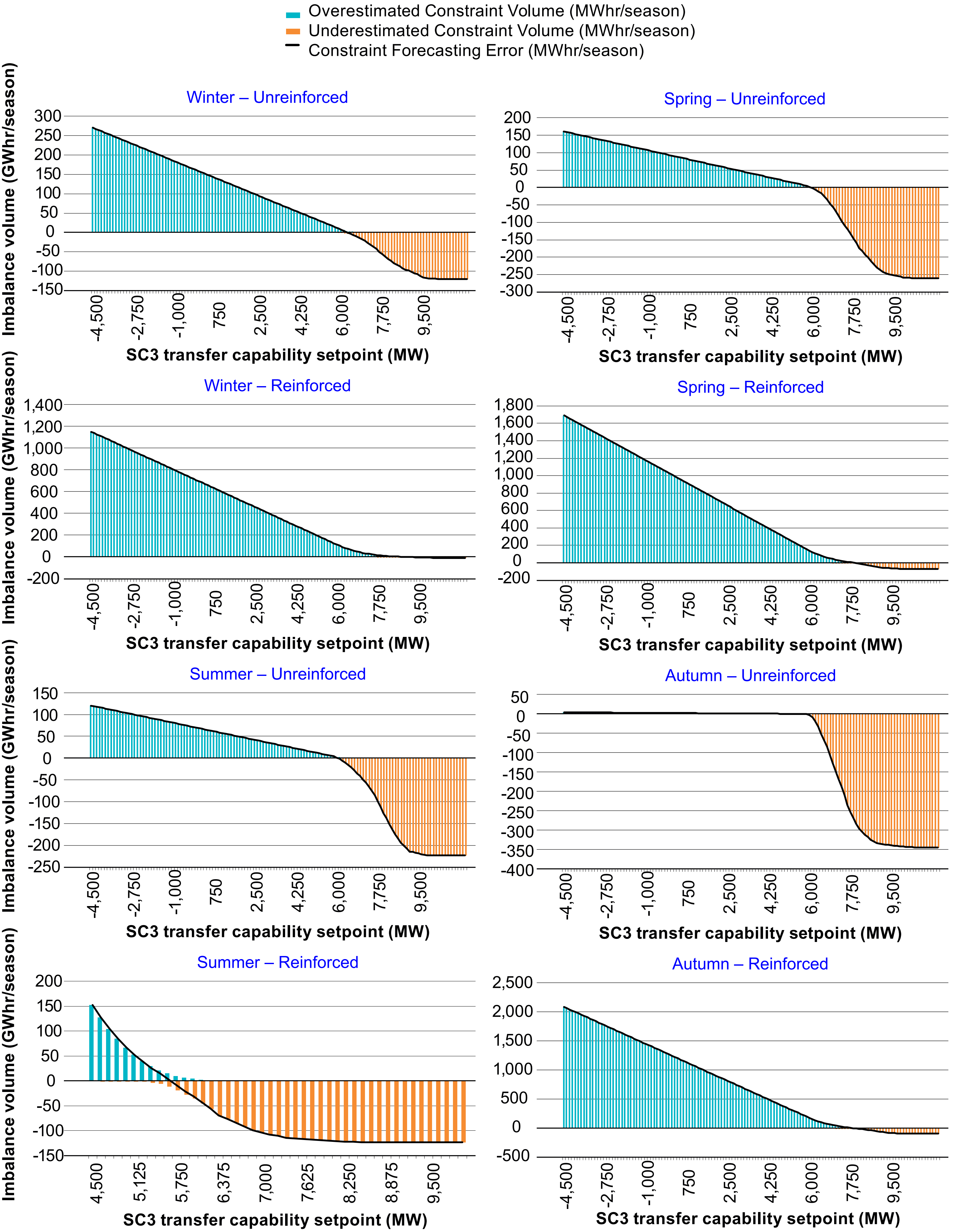


Table 3-5 Year-round probabilistic vs deterministic capability summary for 2027/28 – case 2

Season	Unreinforced network		Reinforced network	
	Probabilistic transfer capability, MW	Deterministic transfer capability, MW	Probabilistic transfer capability, MW	Deterministic transfer capability, MW
Winter	2,325	N/A	4,415	N/A
Spring	2,815	N/A	3,815	N/A
Summer	2,450	N/A	4,065	N/A
Autumn	2,450	N/A	4,065	N/A

The results in this table are derived from Figures 3-11 and 3-12 (zero crossing numbers).

The results show that as the boundary attempts to push out or pull in power across the boundary in the range 4.5GW to -3GW respectively the boundary's capability will be limited by the numbers shown. Within this range interconnector behaviour is split into two negatively correlated groups – that is as one group imports power the other exports power. This makes flows within SC3 complex despite the power transfer requirements being in the middle of the overall requirement range.

The deterministic analysis completely misses this scenario and as such it is not possible to provide commentary of a comparative nature between these two types of analysis. Furthermore, we see that after the application of reinforcements transfer capability is still limited when the two interconnector groups operate in a negatively correlated manner. This means further reinforcements will be required.

We welcome your views and engagement with us on how to best present and communicate probabilistic transmission network capability and requirements via transmission.etys@nationalgrid.com

Figure 3-11 Acceptable and unacceptable boundary flow plots for study year 2027/28

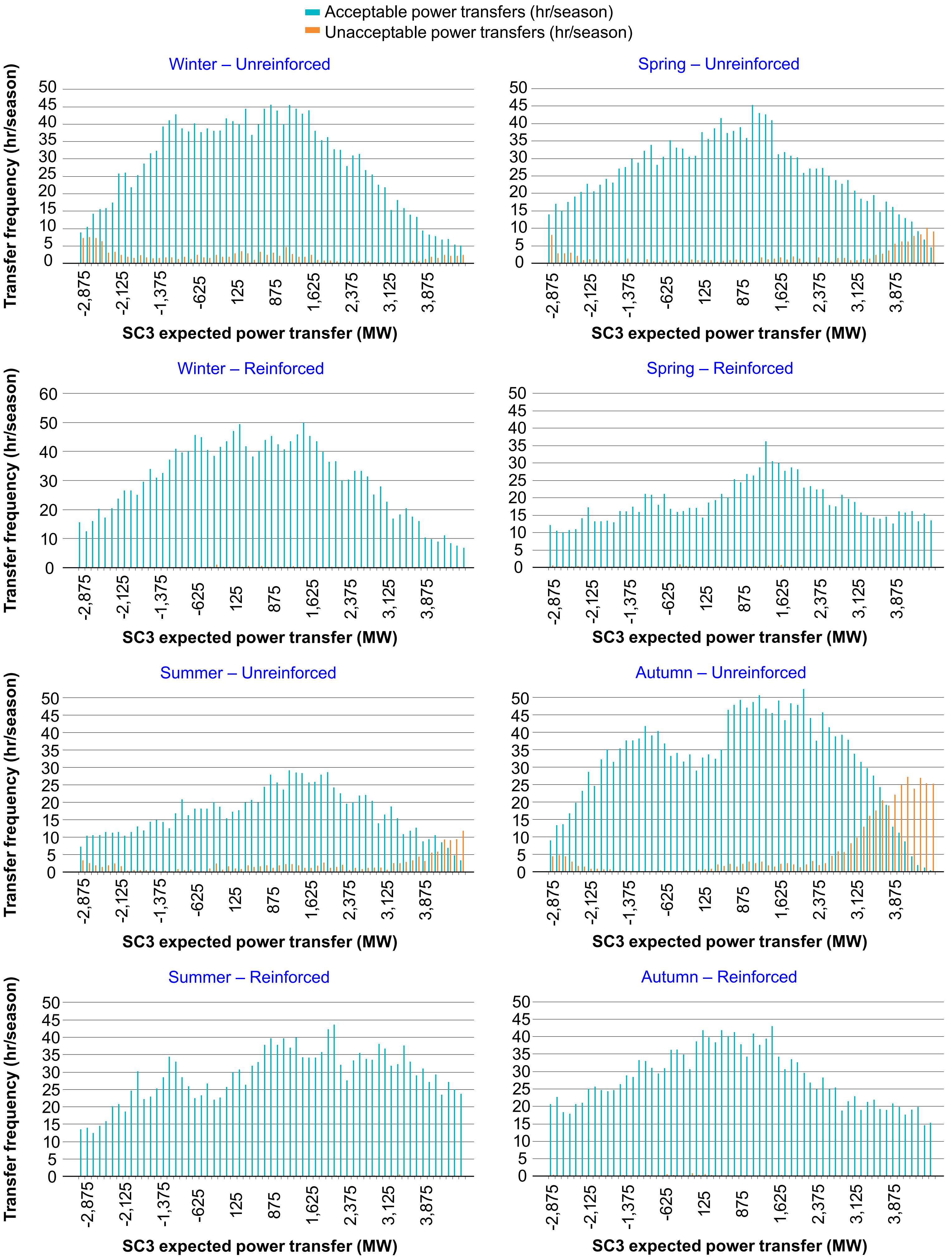


Figure 3-12 Constraint forecast-error probabilistic calculation plots for study year 2027/28

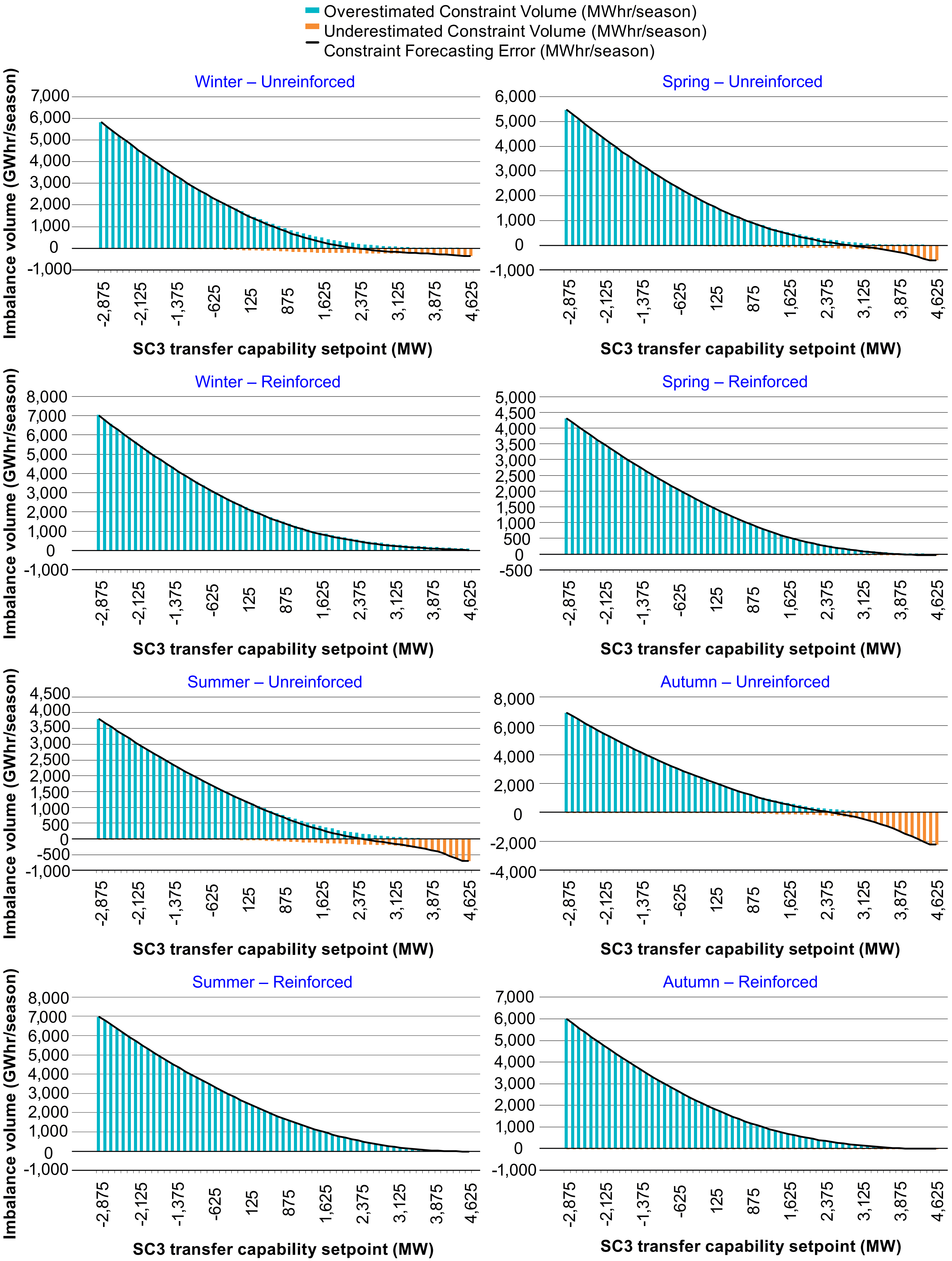


Table 3-6 Year-round probabilistic vs deterministic capability summary for 2027/28 – case 3

Season	Unreinforced network		Reinforced network	
	Probabilistic transfer capability, MW	Deterministic transfer capability, MW	Probabilistic transfer capability, MW	Deterministic transfer capability, MW
Winter	-3,450	N/A	-4,065	N/A
Spring	-3,565	N/A	-4190	N/A
Summer	-3,565	N/A	-4,190	N/A
Autumn	-3,565	N/A	-4,190	N/A

Results in Table 3-6 have been produced from Figures 3-13 and 3-14 (zero crossing numbers).

Table 3-6 has been produced to show that even though solutions are found that allow power to flow when interconnectors are importing or behave in a negatively correlated way, the boundary will still be limited for the conditions when the interconnectors are exporting. Just as mentioned earlier but with effects different to those discussed previously; when the interconnectors export, they place undue stress on certain sections of the network resulting in their special limiting contingencies and circuits.

Once again, the results shown above help reiterate the case that the probabilistic approach allows us to pinpoint specific issues down to the circuit level for key problematic background conditions, so that solutions beyond those currently considered in the *NOA* can be assessed.

We welcome your views and engagement with us on how to best present and communicate probabilistic transmission network capability and requirements via transmission.etys@nationalgrid.com

Figure 3-13 Acceptable and unacceptable boundary flow plots for study year 2027/28

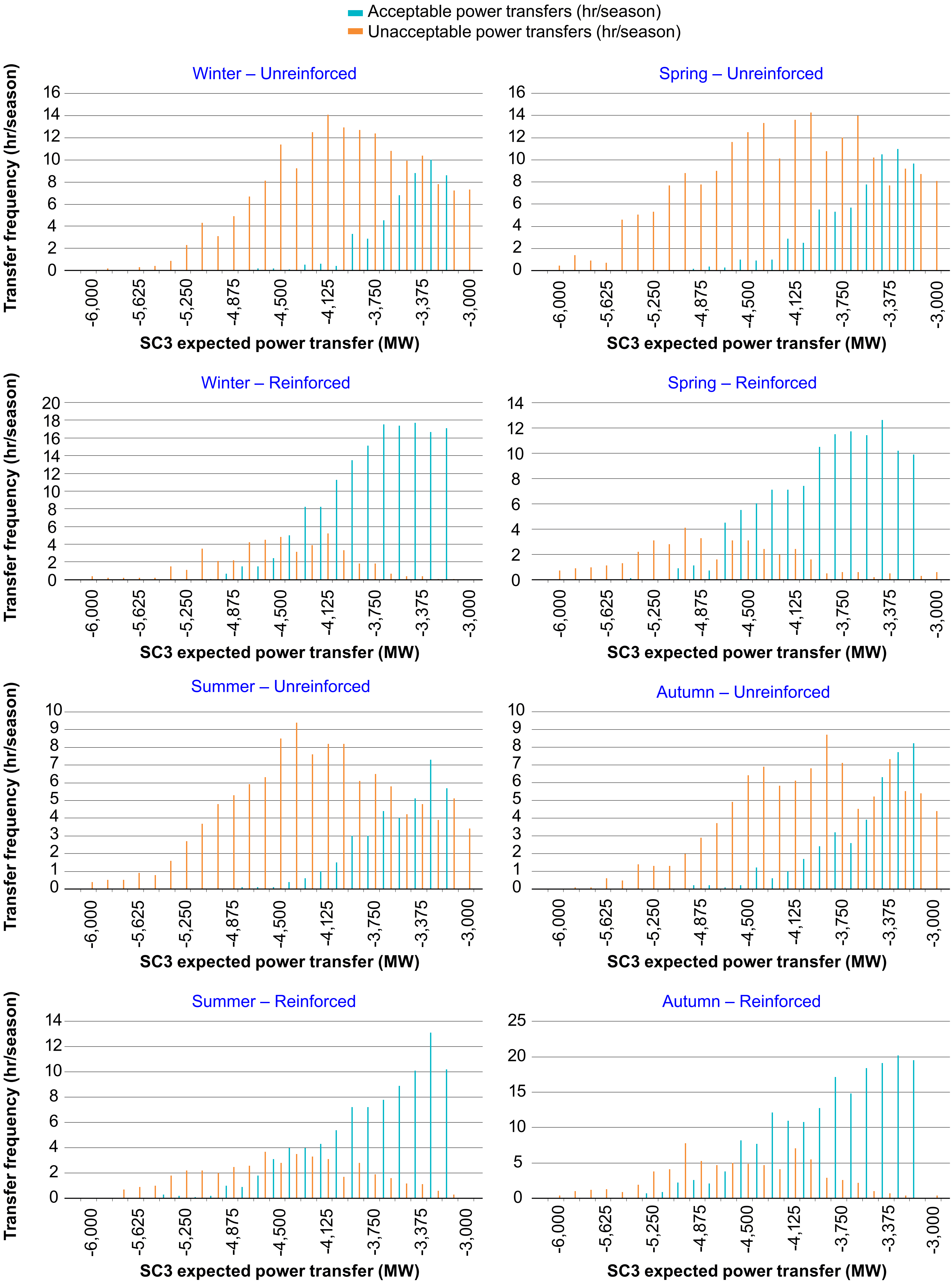
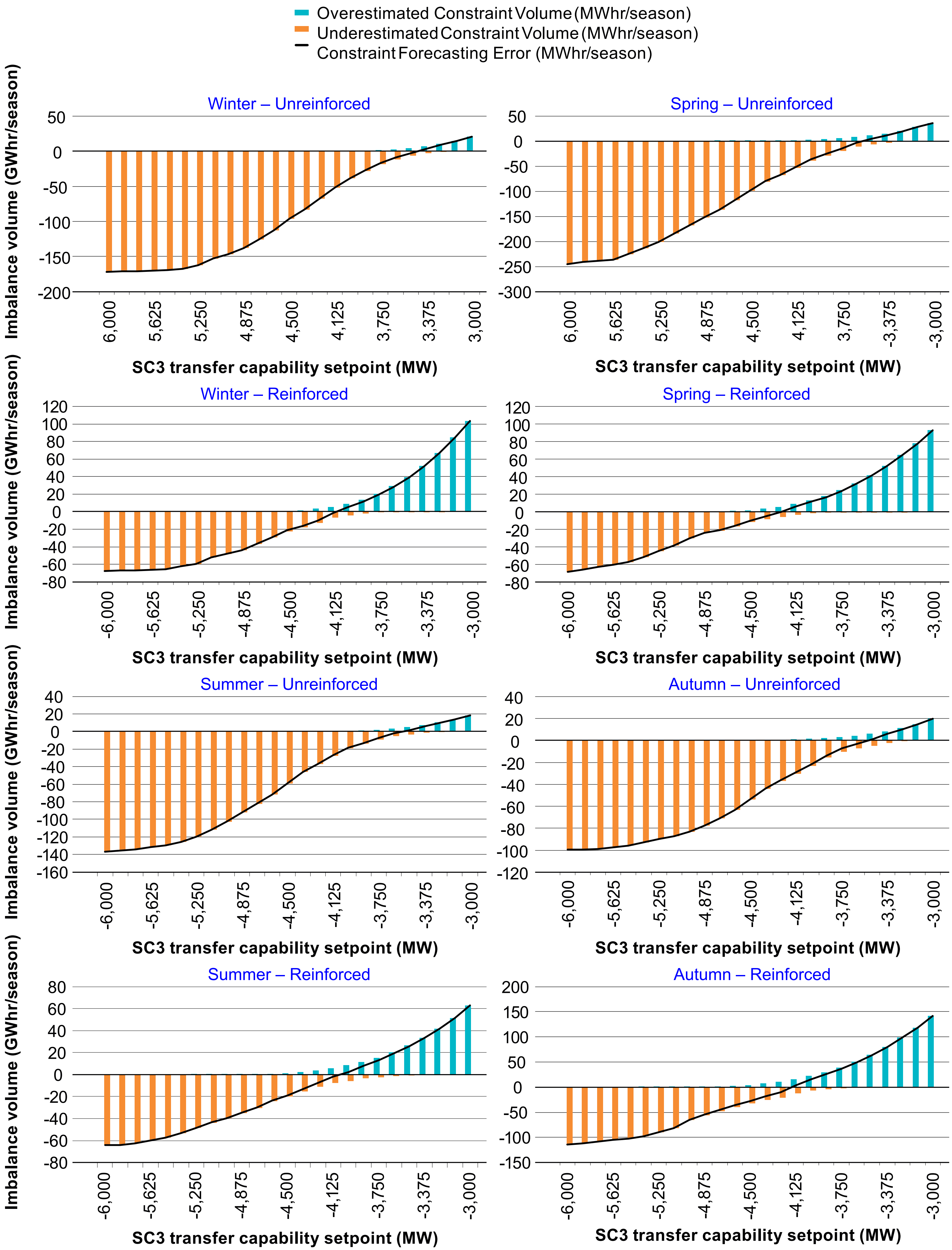


Figure 3-14 Constraint forecast-error probabilistic calculation plots for study year 2027/28



4

The way forward

Our intention is to continue developing our year-round probabilistic thermal assessment capabilities to study requirements across the whole GB. Our studies so far show that our probabilistic approach can identify requirements for a wider range of transmission reinforcement options beyond those currently assessed. Savings from our enhanced network planning could be significant in the years to come, helping to drive additional consumer value.

We have assessed the year-round thermal transmission network needs to greater extent through taking a probabilistic approach. We have carried out a case study on the south-east English coast SC3 boundary. We investigated the probabilistic approach for this one boundary only and presented the results; however, the outcomes could be different for other boundaries. In preparing our case study, we collaborated with National Grid Electricity Transmission (NGET) to establish an up to date understanding of the transmission network asset ratings in the SC3 and wider adjoining areas. We have also engaged with all GB transmission owners over the development of the probabilistic methodology.

As our results are focused on a single region of the GB network we would aim to clarify that we have not fully considered *NOA* options nor do we assess them as they're assessed in the *NOA*. This is to maintain customer confidentiality and prevent bias from not analysing the whole GB network. In this publication, we've used selected *NOA* options as a control to objectively compare the differences we see in the type of results we get between the probabilistic and deterministic approaches. The tools and techniques are still in development and these results are for illustrative purposes to get your views.

We have shown that our probabilistic approach aligns with the deterministic single scenario approach, because the limiting trips and overloaded circuits were similar. However, in many cases the probabilistic approach showed that limiting trips and overloaded circuits appear under generation and demand conditions that where missed by the deterministic approach. Generally, the deterministic approach overestimated SC3 boundary's capability and in most cases resulted in a capability shortfall even after relevant reinforcements were considered. Thus, the probabilistic approach allows us to pinpoint specific issues so that solutions beyond those currently considered (be that network or non-network solutions across transmission and distribution) can be identified. Furthermore, we showed how the probabilistic approach can be used to define dynamic boundary capabilities; to account for complex operational scenarios that limit the boundary differently. From this we can identify key scenario based requirements and develop targeted solutions in a manner that helps drive consumer value.

While the results we present in this publication to showcase our approach to probabilistic network planning are based on the forecast-error constraint concept, we do acknowledge that other methods can be used. We would like to know your thoughts on our proposed approach. Furthermore, we would like to know your thoughts on alternative approaches such as presenting only probability distributions or whether some other risk-based methods could be considered to enhance how we use our results to improve our planning process.

Going forward we will publish our intended use of the probabilistic tool and analysis for year-round thermal analysis for 2019/20 in the *NOA* methodology in Q2 2019. We welcome feedback on the document to help us explore how we can further develop our tool and analysis considering your views. To continue engaging with you we intend to conduct webinars where we can give detailed presentations on the content shared in this document. Please share your views with us via transmission.etys@nationalgrid.com

Faraday House, Warwick Technology Park,
Gallows Hill, Warwick, CV346DA

nationalgrideso.com

nationalgridESO