Future Requirements for Balancing Services

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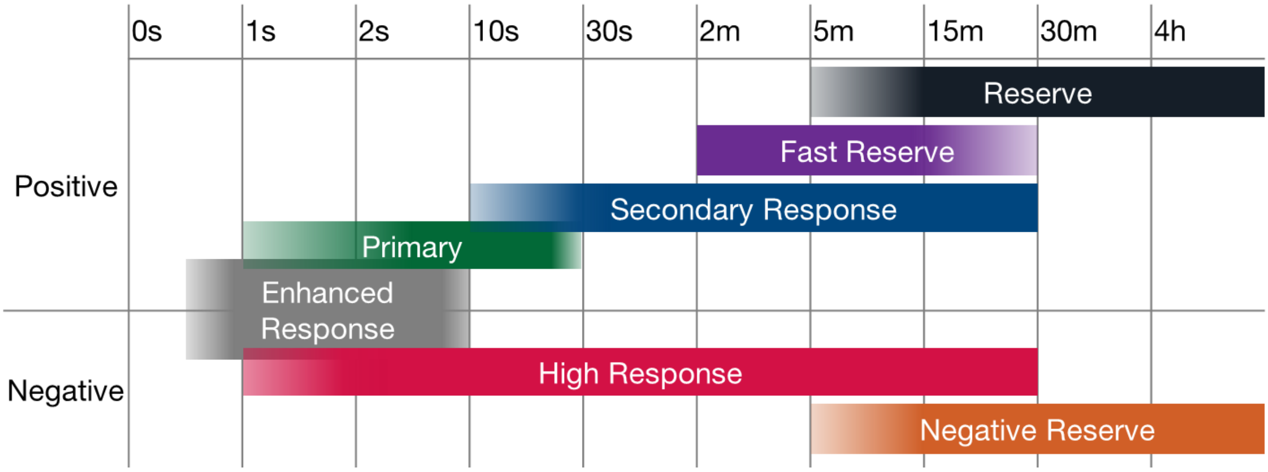
Services

The various balancing services that National Grid procures are characterised by a combination of the direction of the service (‘positive’ or ‘negative’), and the timeframe of the service delivery.

National Grid uses reserve and response services to increase system frequency (positive services) or decrease system frequency (negative services). A positive service provider will either increase its power export, provide power from a standstill or reduce its grid demand, while a negative service provider will do the opposite.



Response services provide power within seconds and are automatically triggered by a local frequency reading, whereas reserve services provide power within minutes triggered by receipt of an instruction.

The various response services have been designed so that it is possible for a single asset to provide all four response services simultaneously. This is represented graphically by overlapping the services.

The various reserve services *can* all be provided by a single asset. Typically only (positive) reserve and negative reserve *are* provided simultaneously by a single asset.

Future Energy Scenarios

In order to calculate the future requirements for any balancing services, a power system background needs to be assumed. When producing this report, and the accompanying dataset, we have used the Gone Green scenario published in the Future Energy Scenarios (July 2015).

Consequently, the exact figures described in this report (and dataset) are a credible illustration of how the future balancing services requirements will evolve. But they should not be considered to be perfectly accurate.

Dataset

Alongside this report, a csv file containing a timeseries forecast for the balancing service requirements has been published.

The data contains eight columns, and represents a forecast timeseries of the requirements:

- Settlement date and period
- Primary, secondary, and high response requirements (MW)
- Positive, negative, and fast reserve requirements (MW)

Several requirements are based on either the weather or the running patterns of large generators and interconnectors. Values for these factors have been forecast to generate a characterisation of requirements over an extended period of time. For example, it is impossible to forecast exactly how windy a given settlement period will be, and therefore the reserve requirement in that settlement period will be incorrect (due to the reserve for wind component).

We have chosen to publish a timeseries for three reasons:

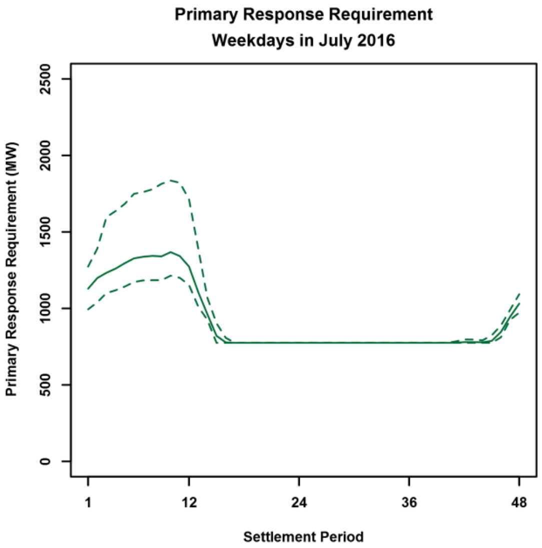
- It illustrates the day to day volatility of the requirements.
- Over the course of a month, the distribution of the requirement will be informative.
- To explain how a given requirement is affected by bank holidays, or the Christmas holiday period.

Occasions where a service is technically insufficient to manage the modelled system conditions are marked by the requirement value of 'NA'. In such cases, a faster response service such as enhanced frequency response would address the issue.

Graphs

All of the graphs in this document have been produced from the dataset published alongside this report. Therefore, if a graph of interest to you has not been produced you should be able to create it.

Most of the graphs in this document have three lines:



The solid line represents the mean value, while the dotted lines show the 2.5% and 97.5% percentile.

For example; the primary response requirement in settlement period 12 on a Monday to Friday in July 2016 are collected. The summary statistics of these 21 samples are then plotted to describe the response requirement at settlement period 12. In this case the values are:

- the mean of the 21 samples is 1274MW,
- the 2.5% percentile of the 21 samples is 1153MW, and
- the 97.5% percentile of the 21 samples is 1711MW.

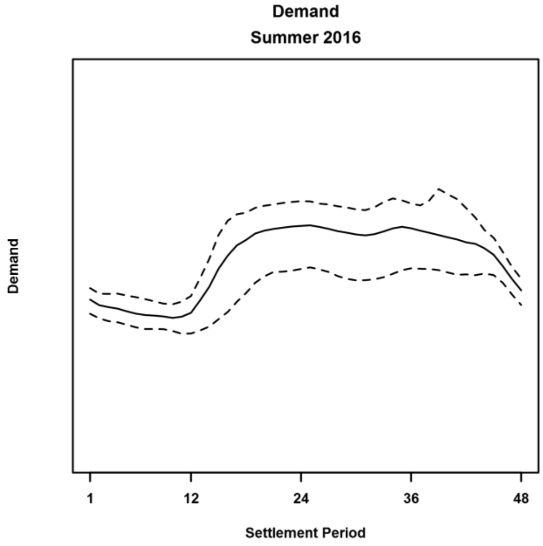
Within this report, all the graphs for a given service have the same limits for the y axis. i.e. all the primary response requirement graphs have a y axis that goes from 0 to 2500MW.

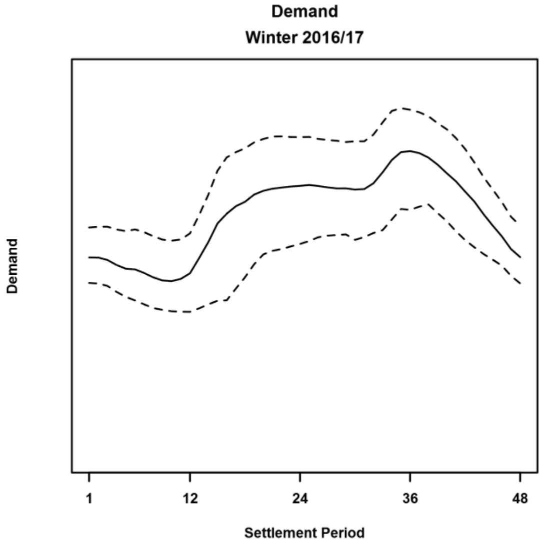
Demand

All off the requirements described in this report change depending on the level of demand. Within this report we use the term 'demand' to refer to the electricity used within GB.

Other reports published by National Grid often talk about transmission demand which is a different figure. The key difference is that when embedded generation output is high the transmission demand will be suppressed, while the demand used in this report is not.

Many of the requirements depend on demand; for example the response requirements are usually lower at times of high demand. Therefore the profile of demand can be seen in the profile of these requirements. To help understand the effect, here are graphs showing the profile of demand across typical summer and winter days:





Frequency Response Requirements

The national electricity transmission system is designed to operate at 50Hz. In practice, the system frequency varies second by second as the balance between system demand and total generation changes. If demand is greater than generation, the frequency falls – if generation is greater than demand, the frequency rises.

After a demand or generation fault there is a significant difference between generation and demand, and therefore system frequency changes. National Grid runs the system to ensure that:

- The maximum deviation of frequency after a normal loss is no greater than 0.5Hz.
- The maximum deviation of frequency after an infrequent loss is no greater than 0.8Hz.
- Any deviations outside 49.5Hz and 50.5Hz do not exceed 60 seconds.

National Grid achieves this by using various response services, which are defined below. The requirement for these frequency response services is set to the lowest amount that is required in order to meet the obligations outlined above.

Primary and secondary response are an automatic increase in generation (or reduction of demand) when the frequency is below 50Hz. Primary response is delivered within 10 seconds, while secondary response is delivered within 30 seconds.

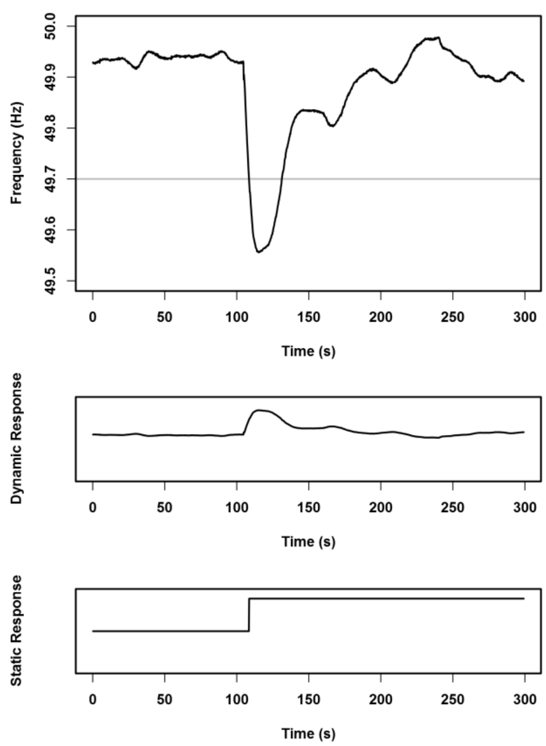
High response is an automatic reduction in generation (or increase in demand) when frequency is above 50Hz. High response, like primary, is delivered within 10 seconds.

Enhanced response is a dynamic service currently under development that delivers automatic changes in power (both increase and decrease) as frequency deviates from 50Hz, delivered within 1 second.

Dynamic / Static Response

Primary, secondary, and high response can all be provided by either dynamic or static services. Dynamic response is characterised as a proportional change in power as frequency changes. Static response is characterised as a fixed change in power after frequency moves beyond a specified limit.

The difference in dynamic and static response delivery for a low frequency event is shown below:



Typically low frequency static response has a trigger level of 49.7Hz which is shown on the frequency graph above.

In order to control frequency pre-fault acceptably, a certain minimum amount of dynamic response is needed. The remainder of the response requirement can be met with either static or dynamic response.

The minimum amount of dynamic response that is acceptable varies with time of day and is higher overnight. The effect of this requirement for a minimum amount of dynamic response can be seen when the requirement is low, i.e. during weekdays during the winter.

Drivers of Frequency Response Requirement

Demand

Sources of demand can generally be considered to fall into one of three categories:

- Actively draw a consistent amount of power regardless of system frequency (e.g. laptop)
- Naturally change power consumption with system frequency, falling as frequency lowers (e.g. domestic electric heater)
- Naturally change power consumption with system frequency while simultaneously contributing inertia to the system (e.g. synchronous electric motor)

Both mechanisms of changing power consumption with respect to system frequency and provision of inertia result in lower frequency response requirements at times of higher demand.

System Inertia

Total system inertia is a function of the demand and generation used to meet that demand. Inertia is related to the energy stored in the rotating masses synchronised to the system, with the prime source contributing to inertia being synchronous generation.

As the total system inertia falls, the speed at which frequency changes after a fault increases. This means that after a certain point primary and high frequency response (with full delivery at 10s) will not be able to fully deliver before frequency has reached the maximum allowable change (0.5Hz or 0.8Hz depending on fault size).

Initially this can be managed by procuring more primary or high response so that it delivers the correct amount of response before 10s (because primary and high response delivery increases over the 10s[1]). For example, if response is needed by 8s it is possible to achieve that by buying 125% of amount with a delivery time of 10s. Alternatively, the same situation can be managed by procuring a quicker service such as enhanced frequency response. In principle, National Grid will manage the situation by procuring whichever service is cheapest.

System inertia is lower overnight (as demand and therefore amount of generation are lower), therefore the increase in primary and high response requirements due to inertia falling will affect night time requirements more so than during the day.

Rate of Change of Frequency

In recent years National Grid has been taking actions in order to limit the rate of change of frequency to 0.125Hz/s. This requirement to limit the rate of change of frequency was driven by protection equipment at embedded sites that would detect a large rate of change and disconnect the site. This protection equipment is known as loss of mains protection.

The distribution code has been modified to require embedded sites to be able to withstand frequency changes of 0.5-1.0Hz/s (depending on capacity). And almost all of the embedded sites have had their protection equipment adjusted, this requirement to limit the rate of change of frequency to 0.125Hz/s is assumed to cease.

[1] A graph showing this increase in power is included in the Enhanced Frequency Response section of this report.

Largest Loss

Response requirements increase as the size of the largest secured loss increases.

Over the next five years, the largest secured generation loss is unchanged at 1260MW until the end of 2019/20. The largest secured demand loss is 560MW for the majority of the time, intermittently increased due to transmission outages or large interconnector flows.

During 2020/21 the largest secured generation (or demand) loss increases to 1400MW and as such the primary, secondary, and high response requirements increase at that time. As the 1400MW loss is due to a new interconnector (NSN link), and the behaviour of flow across that interconnector is unknown at the time of writing; the effect on the average amount of response required is unknown. Although it is certain that the maximum amount of response held will increase in 2020/21.

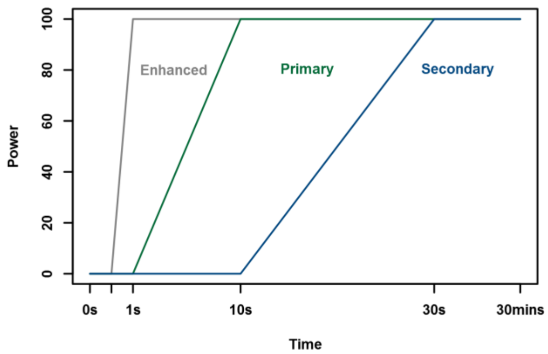
Periods of larger loss sizes due to interconnector flows or transmission outages tend to cluster. This causes clustering effects that can be observed in the requirements.

Enhanced Frequency Response

The frequency response services have been designed to contain frequency after a demand or generator loss, until longer leadtime reserve services can be instructed to return frequency to nominal. As discussed earlier, lower system inertia and/or larger losses cause the frequency to move more quickly and therefore create more severe frequency events for frequency response services to contain.

Enhanced frequency response is a dynamic response service, which has initially been specified[2] to fully deliver within 1s compared to 10s for primary frequency response. Therefore, one can consider enhanced frequency response as speeding up existing conventional primary and high frequency response services.

Enhanced frequency response has been designed to dovetail with the existing primary, secondary and high response services. Therefore a single unit can provide enhanced, primary, secondary and high response simultaneously. This can be illustrated by showing the power delivery of this single unit for a low frequency event:

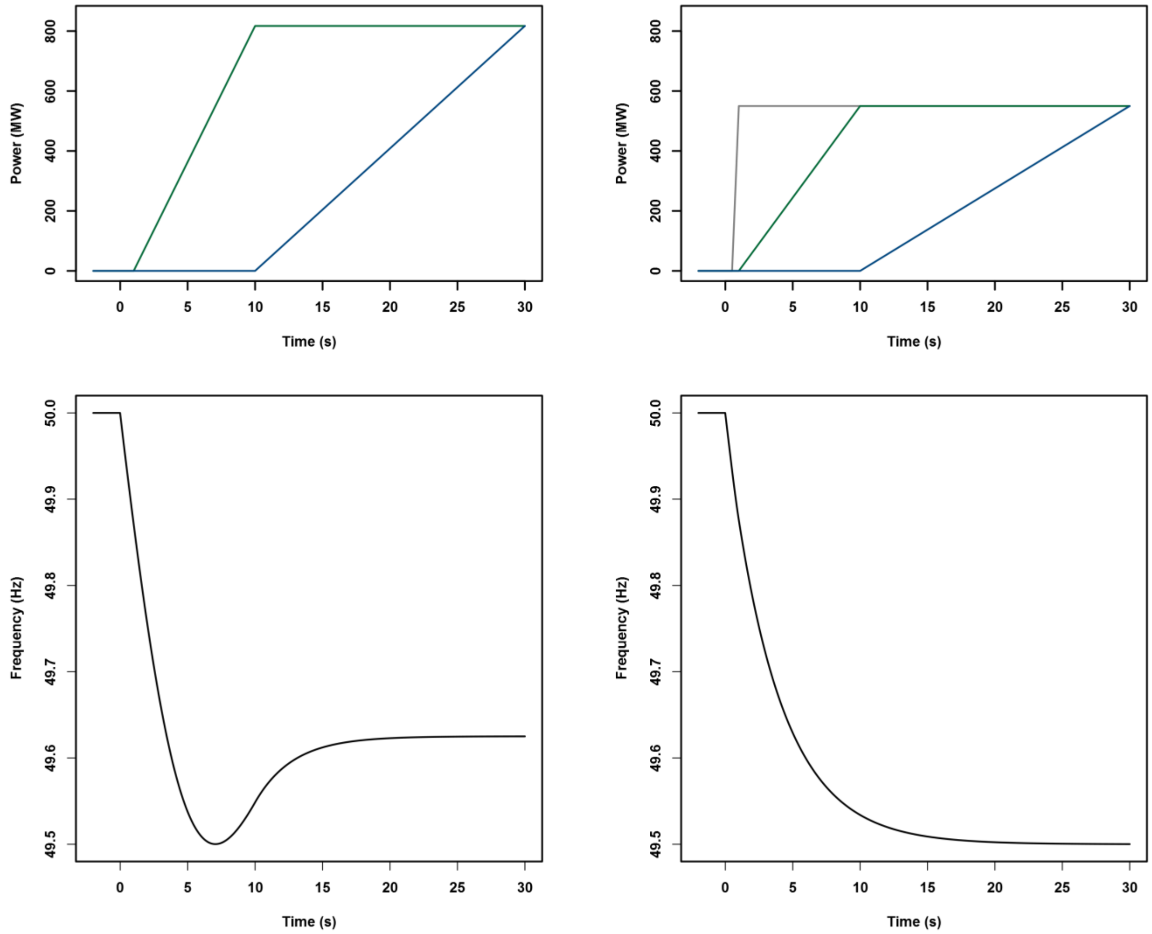


In the coming months, the detailed specification of enhanced frequency response will be published. This specification is, in part, influenced by the replies to the 'Invitation for Expressions of Interest in Provision of Enhanced Frequency Response'.

[2] Invitation for Expressions of Interest in Provision of Enhanced Frequency Response http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=42966

Why is Enhanced Frequency Response Needed?

At times when system inertia is low, the quicker response allows less power (and therefore less response) to contain frequency after a loss. For the same system conditions, 550MW of enhanced, primary and secondary response can be compared with 817MW of primary and secondary response:



During system conditions when inertia is low, the frequency will reach a minimum value some time before primary response has fully delivered at 10s. This can be managed by increasing the amount of primary response held so that the correct amount can be delivered at that time, this has the consequence that when primary response fully delivers at 10s the frequency will have ‘bounced’ a certain amount.

Alternatively, the same system conditions can be managed by holding the correct amount of response using the enhanced frequency response service. Because this response will fully deliver by 1s it will already be delivering well before the frequency gets close to the limits.

Eventually as inertia falls, using primary/high response services only, the bounce that occurs after the initial frequency minimum will increase. And for low enough inertia the frequency will oscillate, indicating that the system requires a service such as enhanced frequency response.

Treatment of Enhanced Frequency Response in this Report

In this report (and datafile) we have assumed that no enhanced frequency response exists. This means that the primary and high response requirements are higher than they would be if enhanced frequency response was procured. If inertia is low enough to cause the frequency to move so quickly that primary response becomes technically insufficient and a faster service such as enhanced frequency response is needed, the dataset provided alongside this report will have primary / high response requirements set to ‘NA’.

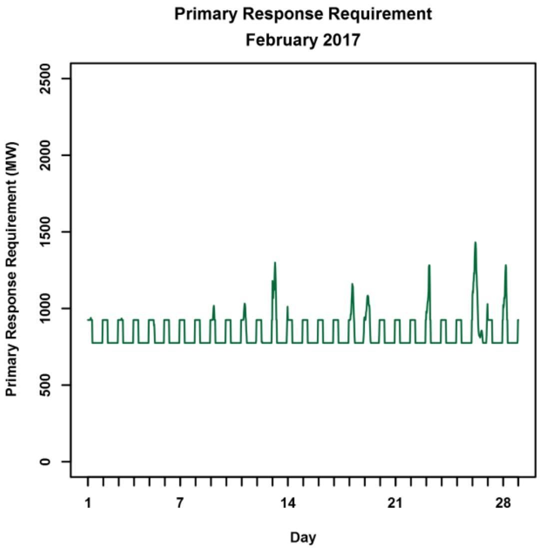
Primary Response Requirements

Primary response is an automatic increase in generation (or reduction of demand) when the frequency is below 50Hz, delivered within 10 seconds.

The main driver behind the primary response requirement is system demand; at times of lower system demand the primary response requirement is higher. A second driver is the need for at least a minimum amount of primary dynamic response.

Timeseries

The graph below show the primary response requirement over a month:

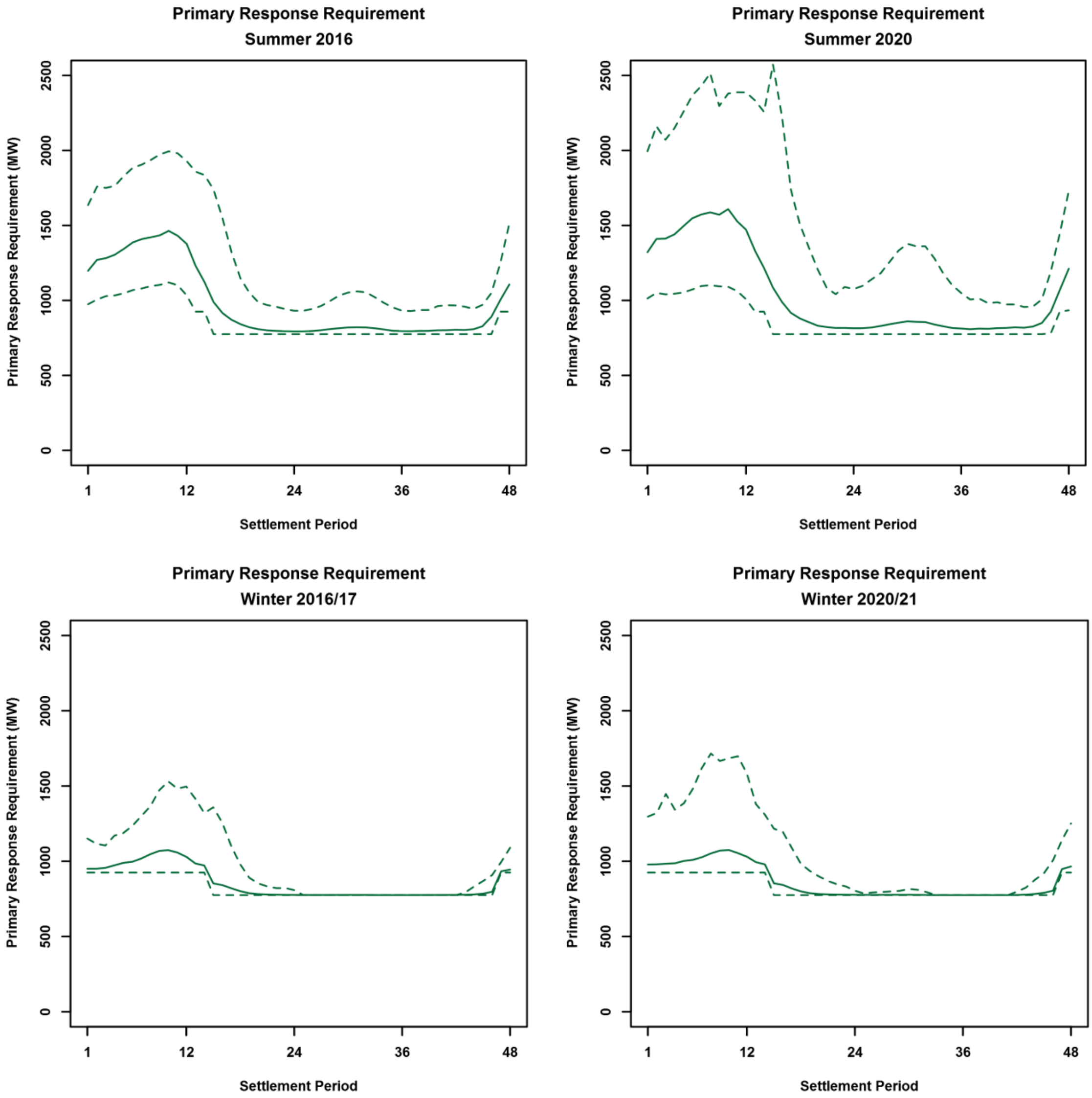


From the graph; it is easy to see that the primary response requirement has a clear diurnal pattern, with a few clusters of days where the requirement is significantly higher.

The diurnal pattern is driven by a minimum dynamic primary response requirement in the winter. During the summer, when demand is lower, the response requirements are larger and the minimum dynamic requirement is often not the biting requirement. But, due to the diurnal pattern of demand, the response requirement continues to have a large diurnal pattern.

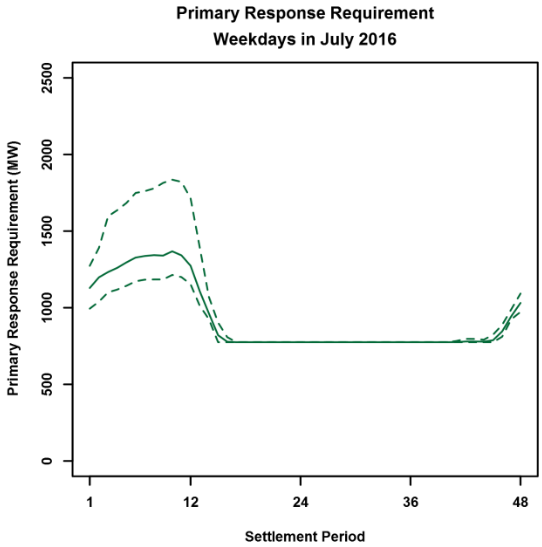
Diurnal and Yearly Seasonality

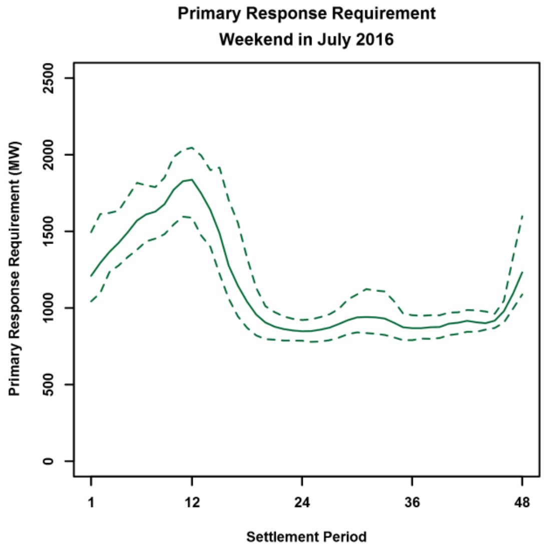
As stated above; the primary response requirement is higher at times of lower system demand, as such the requirement is higher overnight and more so in the summer. As the power system evolves over the next five years, we expect demand to fall slightly and therefore the primary response requirement to increase:



Weekly Seasonality

Demand is similar for all weekdays and substantially lower during the weekends. Therefore the primary response requirement is higher at the weekend:



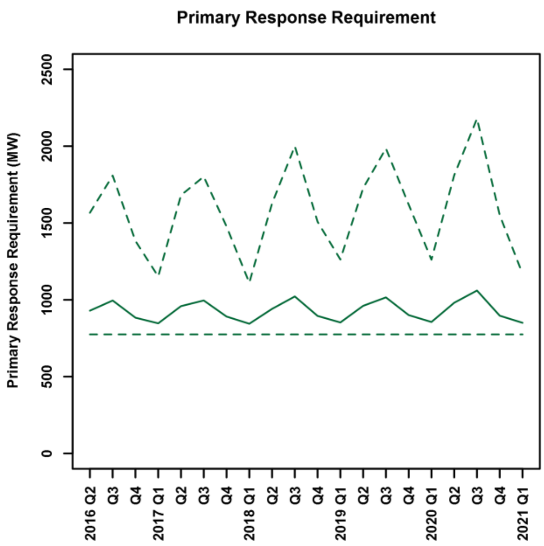


Lowering System Inertia

System inertia is lower overnight (as demand and therefore amount of generation are lower), therefore the increase in primary response requirements due to inertia falling will affect night time requirements more so than during the day.

Overview

The graph below gives a broad overview of how much the envelope of primary response requirement changes over the next five years (due to the effects outlines above):



In summary, most of the time, the requirement for primary response is unchanged. But days when there is low system inertia (and therefore a need to hold more primary response) become more frequent. This can be seen on the graph as the top dotted line increasing.

In 2020/21 the largest loss increases which causes an increase in the amount of primary response required. As can be seen above, this effect is minor compared with the yearly increase in the amount of primary response required due to the yearly reduction in demand and inertia.

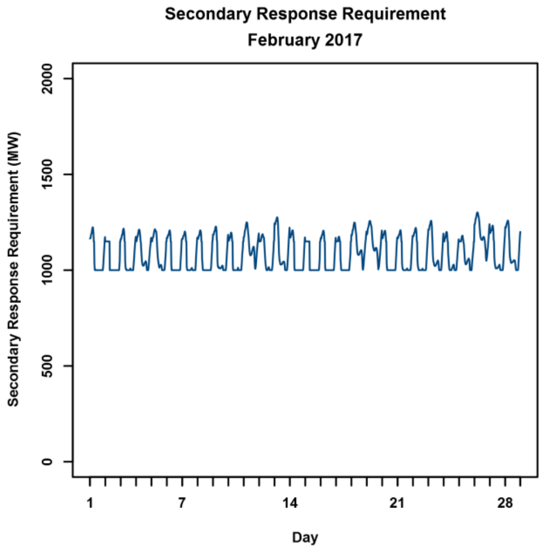
Secondary Response Requirements

Secondary response is an automatic increase in generation (or reduction of demand) when the frequency is below 50Hz, delivered within 30 seconds.

The main driver behind the secondary response requirement is system demand; at times of lower system demand the primary response requirement is higher. A second driver is the need for a least a minimum amount of secondary dynamic response.

Timeseries

The graph below shows the secondary response requirement over a month:

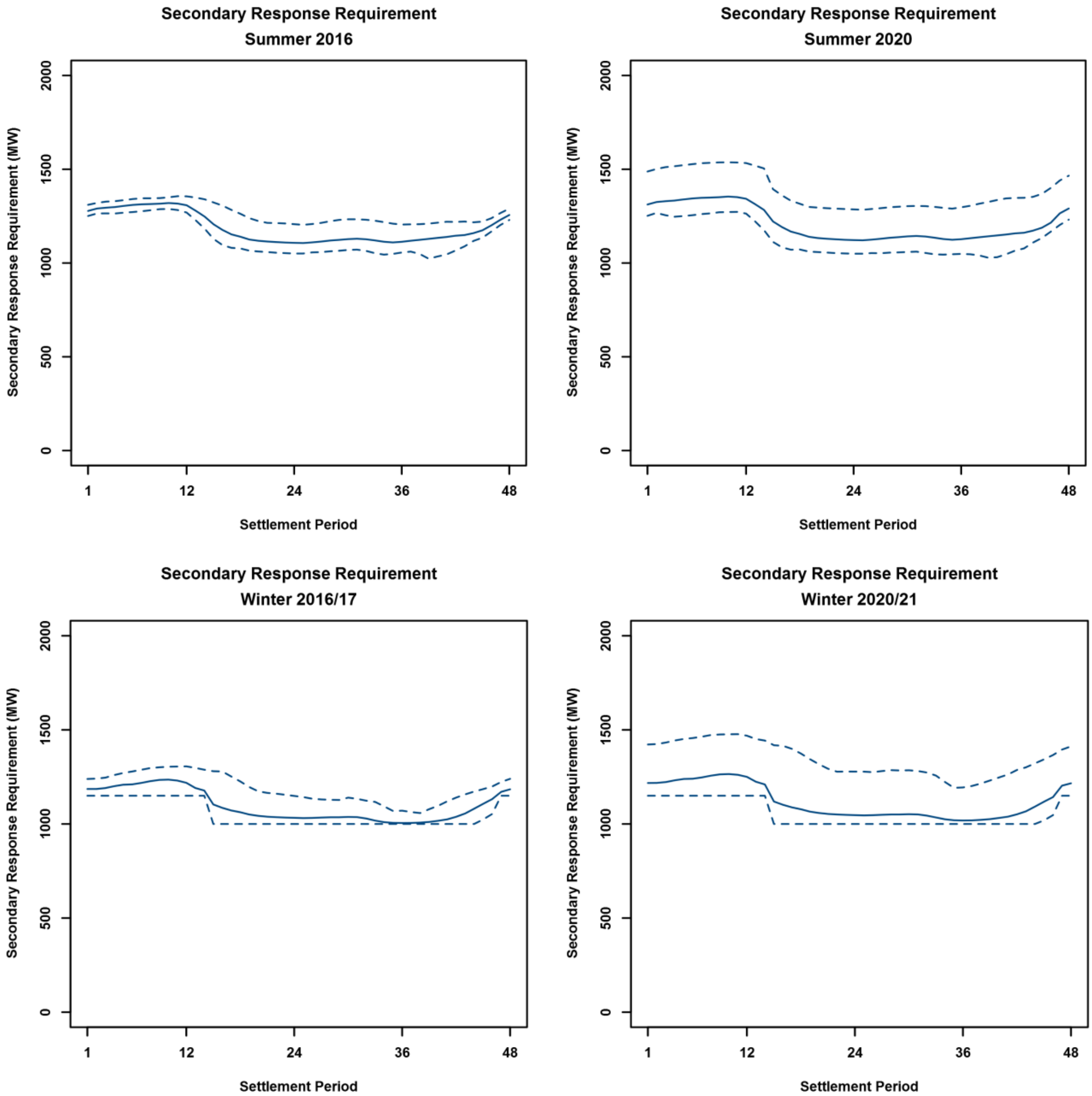


From the graph; it is easy to see that the secondary response requirement has a clear diurnal pattern, with clusters of days where the requirement is higher.

During the winter, the diurnal pattern is driven by the minimum dynamic secondary response requirement. During the summer, when demand is lower and therefore the response requirements are larger, the minimum dynamic requirement is often not the biting requirement. But, due to the diurnal pattern of demand, the response requirement continues to have a diurnal pattern.

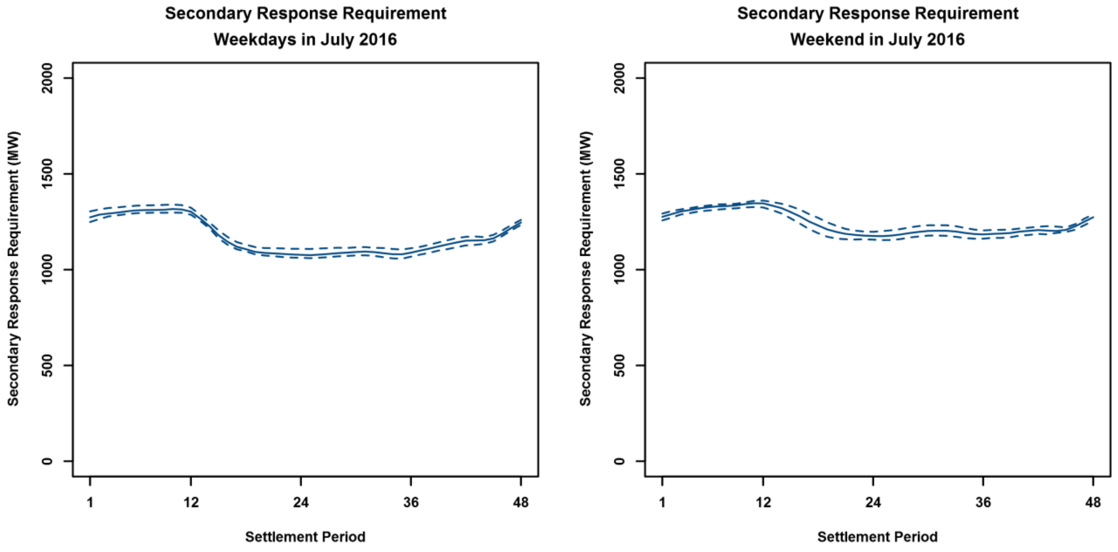
Diurnal and Yearly Seasonality

As stated above; the secondary response requirement is higher at times of lower system demand, as such the requirement is higher overnight and more so in the summer. As the power system evolves over the next five years, we expect demand to fall slightly and therefore the secondary response requirement to increase:



Weekly Seasonality

Demand is similar for all weekdays and substantially lower during the weekends. Therefore the secondary response requirement is higher at the weekend. This effect is less pronounced for secondary response (compared with primary response) as the requirement in general is higher:

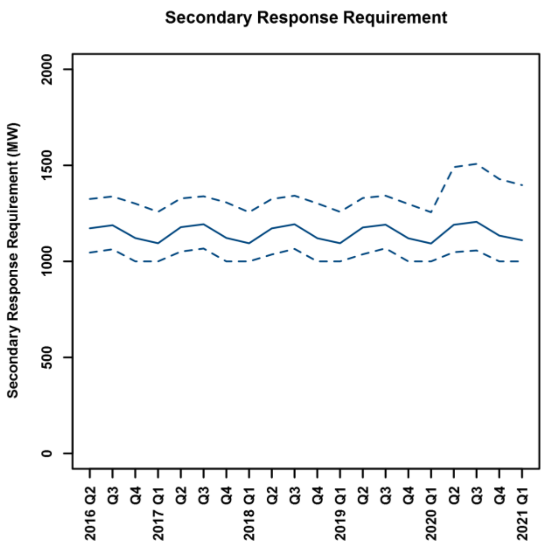


Lowering System Inertia

Lowering system inertia does not change the secondary response requirement.

Overview

The graph below gives a broad overview of how much the envelope of secondary response requirement changes over the next five years (due to the effects outlines above):



In summary, most of the time, the requirement for secondary response is unchanged. In 2020/21, the largest loss increases to 1400MW – this has been modelled this by including a 1400MW loss on a few of the days in in 2020/21 i.e. the average line in the graph is largely unaffected, but the 97.5 percentile is around 140MW higher.

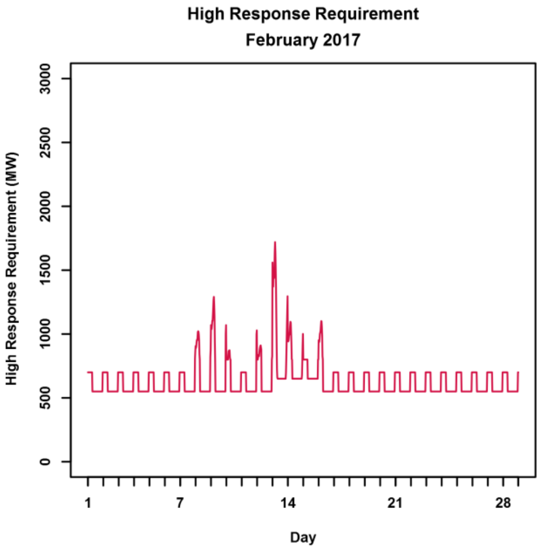
High Response Requirements

High response is an automatic decrease in generation (or increase of demand) when the frequency is above 50Hz delivered within 10 seconds.

The main driver behind the high response requirement is system demand; at times of lower system demand the high response requirement is higher. A second driver is the need for a least a minimum amount of dynamic response.

Timeseries

The graph below show the high response requirement over a month:



From the graph; it is easy to see that the high response requirement has a clear diurnal pattern, with a few clusters of days where the requirement is significantly higher.

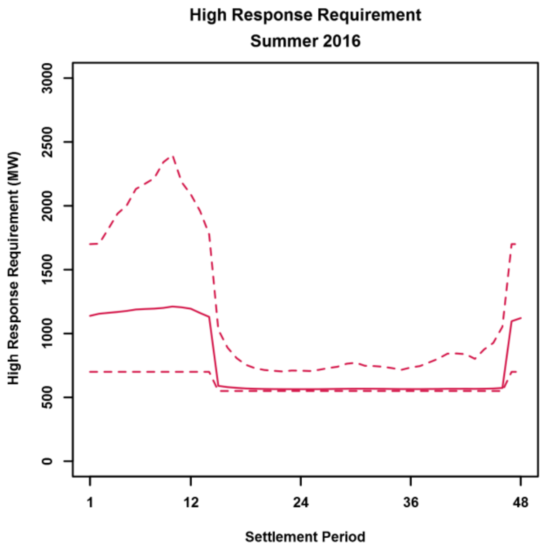
The diurnal pattern is usually driven by a minimum dynamic high response requirement.

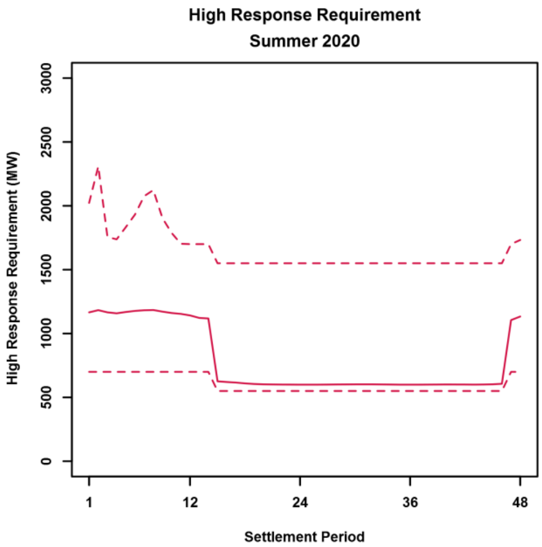
The periods where the requirement is significantly higher is driven by the increased secured demand loss due to interconnector flows exporting from GB.

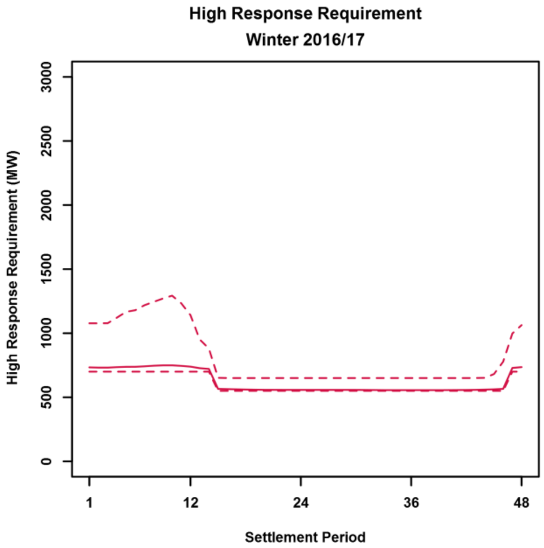
Diurnal and Yearly Seasonality

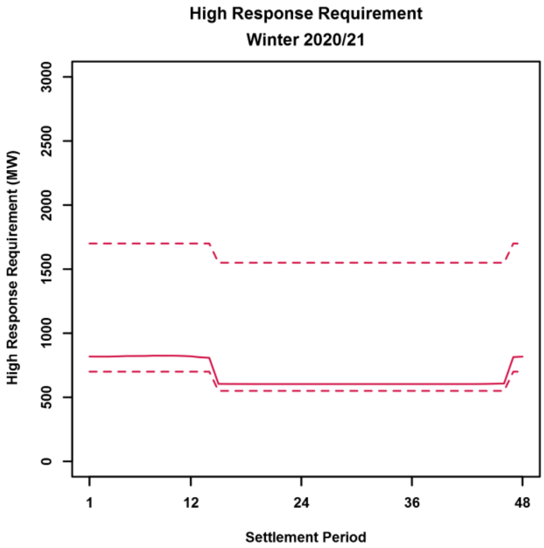
As stated above; the high response requirement is higher at times of lower system demand, as such the requirement is higher overnight and more so in the summer. As the power system evolves over the next five years, we expect demand to fall slightly and therefore the primary response requirement to increase.

The system is secured for a largest demand loss size of 560MW for the majority of the time, unless interconnector flows or transmission outages require a larger demand risk to be secured. As transmission outages are skewed towards the summer the response requirements are higher in summer:



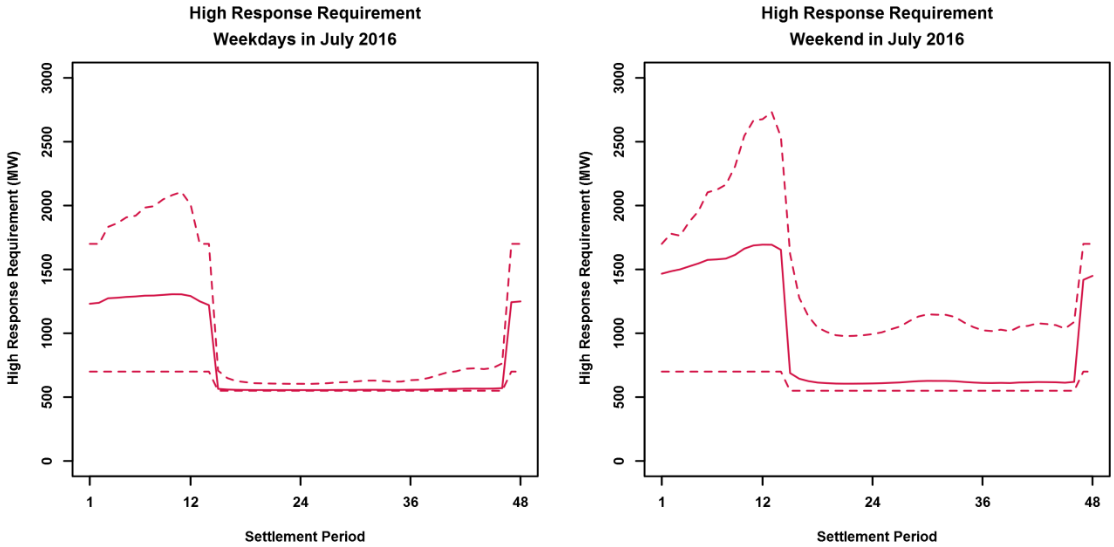






Weekly Seasonality

Demand is similar for all weekdays and substantially lower during the weekends. Therefore the high response requirement is higher at the weekend:

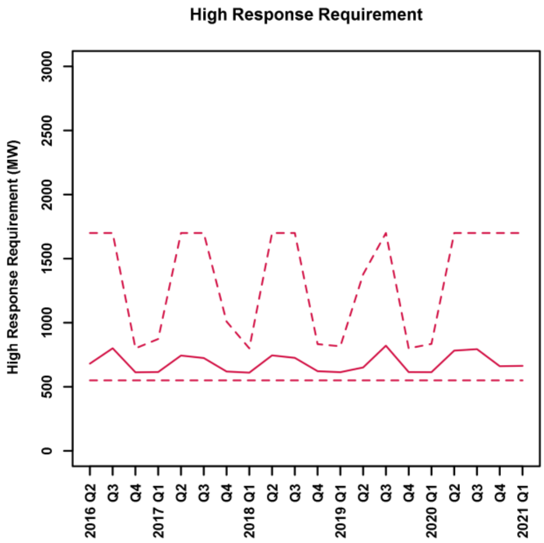


Lowering System Inertia

System inertia is lower overnight (as demand and therefore amount of generation are lower), therefore the increase in high response requirements due to inertia falling will affect night time requirements more so than during the day.

Overview

The graph below gives a broad overview of how much the envelope of high response requirement changes over the next five years (due to the effects outlined above):



In summary, the requirement for high frequency response is higher during the summer. In 2020/21 the largest loss increases which causes an increase in the amount of high response required. This can be seen as widening the range of requirements from Q2 2020 onwards.

Reserve Requirements

Reserve is the generic term utilised by National Grid to represent the aggregate amount of additional generation capacity above demand that National Grid maintains in the period four hours ahead of real time and real time.

National Grid maintains a volume of reserve[3] to ensure that it is able to match generation to demand on a second by second basis while responding to a range of demand forecasting errors or unexpected generation changes. There are positive and negative reserve requirements, each of which is comprised of different elements:

The levels of the above reserves vary on a day to day basis with a number of factors influencing exactly how much reserve National Grid needs to maintain.

Reserve is comprised of a number of different types of reserve, each with their own particular characteristics and reasons for being maintained. These different elements are each described in turn below:

Basic Reserve

Basic reserve is the quantity of reserve required to manage the variation between expected and actual non-wind generation and demand between a point four hours ahead of real time and real time.

The overall requirement for basic reserve is calculated using a statistical analysis of historic non-wind plant losses and demand forecasting errors and is set with the objective that there is no more than a 1 in 365 chance (or alternatively a 99.7% confidence) that the demand could exceed available generation (excluding losses of wind/solar output). As the non-wind generation mix and leadtime change, the risks change and therefore the basic reserve level changes.

Wind Reserve

Wind reserve is a reserve held by National Grid specifically to manage the additional variability in generation between four hours ahead of real time and real time caused specifically by wind generation. Its value varies based upon a function of the expected wind output through each period of the day. Rapid changes can be driven by unstable gusty wind patterns over areas where there are a high number of wind generators. Or alternatively by mass cut-out of large numbers of wind turbines as they shut down for safety reasons when the local wind speed exceeds the safe operating parameters of the wind turbine (approximately 60-80mph). It is this phenomenon known as wind cut-out that can lead to the largest and most rapid changes in wind generator output and although a high volume of it is likely to be forecast in the four hour ahead wind generation forecast, and therefore a key driver of when the largest volumes of wind reserve are required.

Photovoltaic (PV) Reserve

Solar PV reserve is held reserve held by National Grid specifically to manage the additional variability in demand between four hours ahead of real time and real time caused specifically by lower than expected solar PV output. Its value varies based upon a function of the expected PV output through each period of the day.

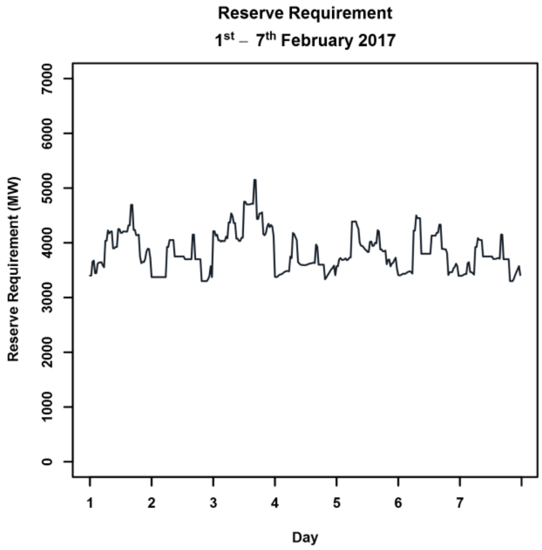
[3] Reserve requirement is often referred to as 'operating reserve requirement'.

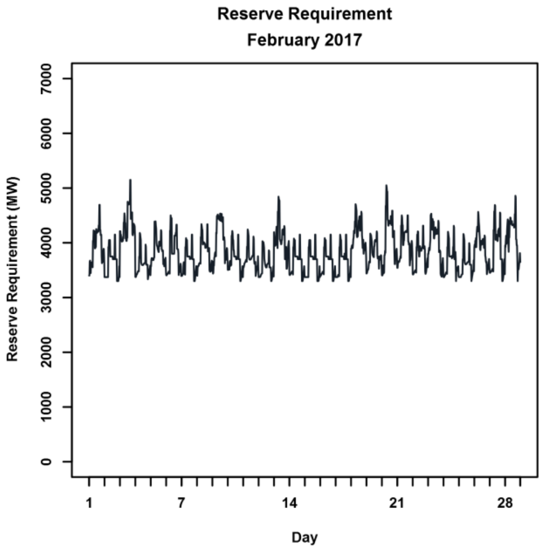
Reserve for Low Frequency Response
National Grid procures frequency response services to help maintain a system frequency around a target of 50Hz. Any response that is held on conventional units requires the unit to be deloaded, which has the effect of sterilising the reserve these units could otherwise have provided. Therefore at times with larger response requirements, the reserve requirement is increased.

Short Term Operating Reserve (STOR)
STOR is a contract form to provide reserve, it can be used to meet most of the requirement above.

The amount of STOR actually held is an economic assessment of its value compared with the forecast costs of procuring the same quantity of reserve within the balancing mechanism.

Timeseries
There is a wide variation in positive reserve requirements from day to day, the requirements over the month below show typical spreads of 3000 to 6000MW:



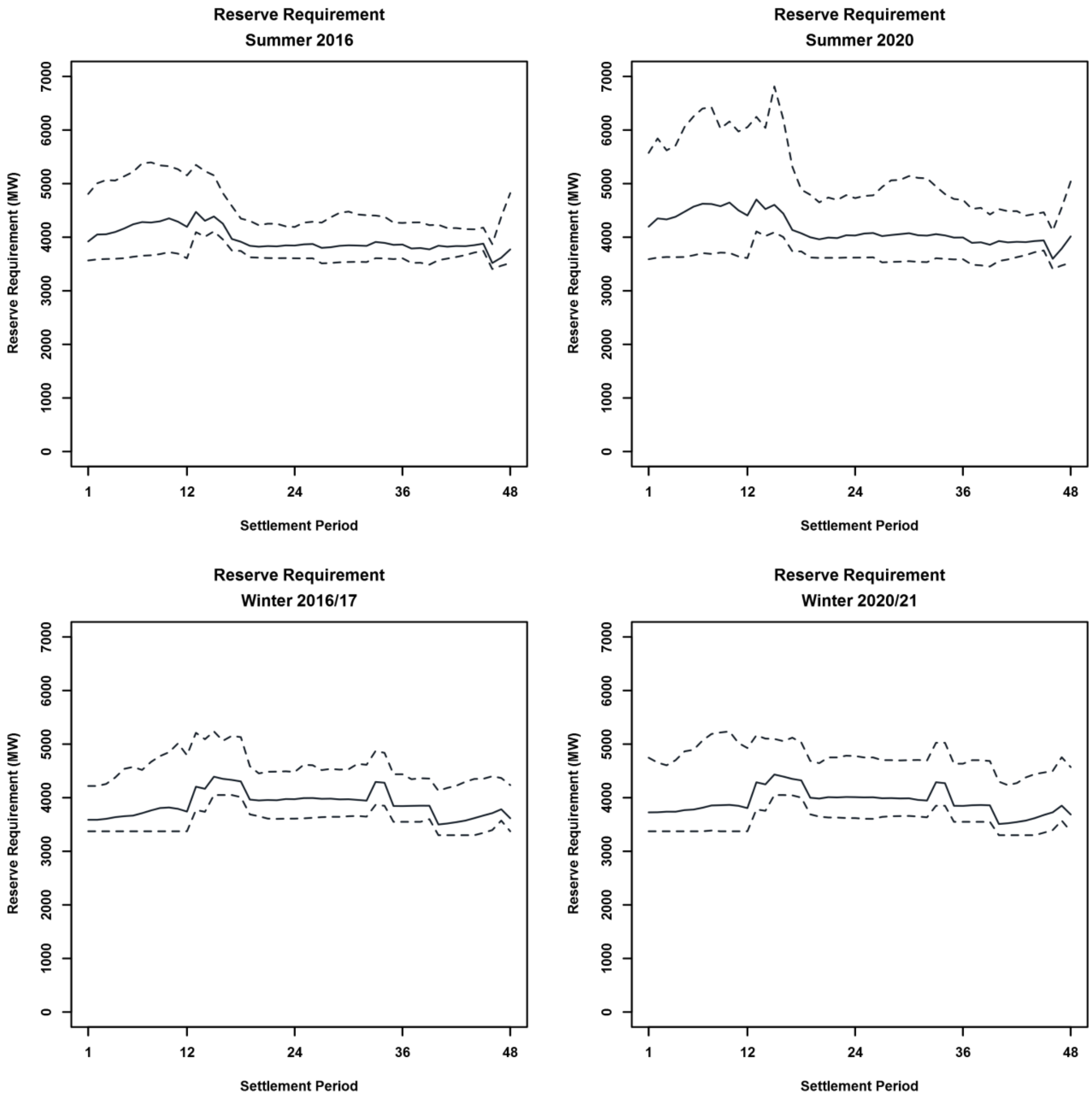


The change in requirements over short timescales is due to combinations of the following criteria:

- Reserve for low frequency response due to low system inertia (particularly applicable over overnight periods, settlement periods 46 to 16).
- Reserve profile, where higher basic reserve is needed over national demand ramp periods where rate of change of demand is high (morning ramp and darkness peak ramp periods).
- Periods of high wind generation where additional wind reserve is needed.

Diurnal and Yearly Seasonality

The plots below present the expected change to both the winter and summer reserve profiles between 2016 and 2021. The profiles assume that there is still a typical daily national demand shape on the transmission system, with peak and minimums demands consistent across all years:



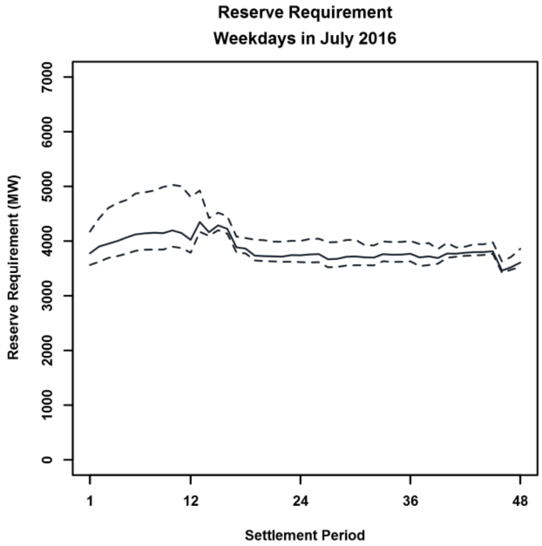
The increase in requirements for summer overnight is primarily due to the changes in the amount of reserve for low frequency response. As the amount of primary frequency response required changes (due to low system inertia overnight), the amount of reserve for low frequency response increases.

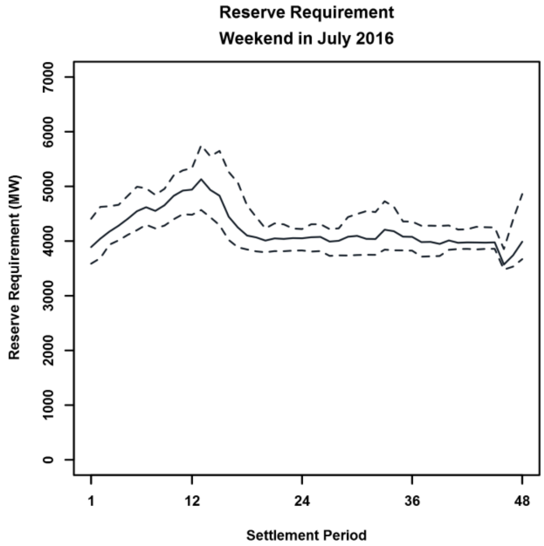
As wind capacity grows, the range of wind reserve requirement increases, which can be seen on the graphs above as a wider band between the 2.5 and 97.5 percentile requirements. In summer, the wind generation load factor is lower than winter, hence the difference between 2.5 and 97.5 percentile requirements are closer in the summer than in the winter.

As solar capacity grows, the range of PV reserve requirement increases, which can be seen as an increase in the range of reserve requirements over the summer daytime in 2020/21.

Weekly Seasonality

The reserve requirement is significantly different between weekdays and weekends. The higher reserve requirement overnight is brought about by the need for more reserve for low frequency response. This is particularly applicable over summer weekends overnight, where the demand is lower and therefore the primary response requirement is highest:

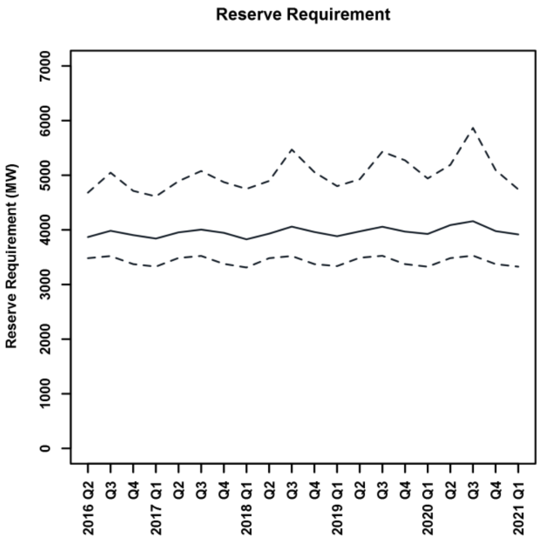




Additionally, on weekdays a higher basic reserve is needed over the morning demand pickup (periods 15 to 18) where rate of change of demand is high.

Overview

The graph below gives a broad overview of how much the envelope of reserve requirement changes over the next five years (due to the effects outlines above):



In summary, the requirement for reserve is increasing gradually over the coming years.

The reserve requirement increases each year as more wind generation connects to the system in order to cover the uncertainty in wind output. In addition, the range of wind output increases, and therefore the range of National Grid's requirement for reserve increases. The maximum positive reserve requirements are usually caused by high forecast wind output. Conversely, the minimum requirement is usually caused by low forecast wind output.

The increase in primary and secondary response requirements causes an increase in the amount of reserve for response required. This is particularly noticeable in 2020/21, when the largest loss increases which causes an increase in the amount of response required. As can be seen above, this effect is minor compared with the yearly increases due to the yearly increases in reserve for wind and solar.

Negative Reserve Requirements

Negative reserve is the generic term utilised by National Grid to represent the aggregate amount of footroom that National Grid maintains in the period four hours ahead of real time and real time.

Negative reserve is comprised of a number of different types of negative reserve, each with their own particular characteristics and reasons for being maintained. Like (positive) reserve, negative reserve is comprised of a regulating reserve, wind reserve, PV reserve and reserve for response.

Basic Negative Reserve

Basic negative reserve is the quantity of negative reserve required to manage the variation between expected and actual non-wind generation and demand between a point four hours ahead of real time and real time.

The overall requirement for basic negative reserve is calculated using a statistical analysis of historic non-wind plant losses and demand forecasting errors and is set with the objective that there is no more than a 1 in 365 chance (or alternatively a 99.7% confidence) that the generation (when curtailed at short notice) could exceed demand (excluding losses of wind/solar output). As the non-wind generation mix and leadtime change, the risks change and therefore the basic negative reserve level changes.

Wind Negative Reserve

As wind generation is controllable, and it is always possible to reduce its output power, there is no need to carry addition negative reserve on windy days.

Photovoltaic (PV) Negative Reserve

Solar PV negative reserve is held reserve held by National Grid specifically to manage the additional variability in demand between four hours ahead of real time and real time caused by higher than expected solar PV output. Its value varies based upon a function of the expected PV output through each period of the day.

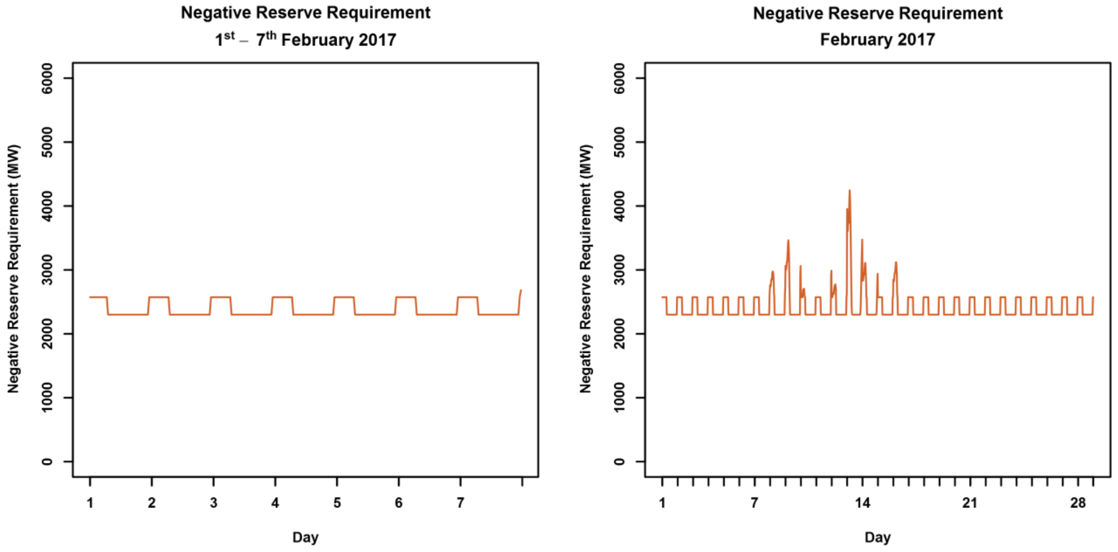
Unlike wind generation, if the PV output exceeds expectation it is unlikely that National Grid can curtail its output. Therefore there is a need to hold additional negative reserve on cloudy days (this reserve would be used if the clouds were to clear).

Negative Reserve for High Frequency Response

National Grid procures frequency response services to help maintain a system frequency around a target of 50Hz. Any response that is held on conventional units requires the unit to be loaded, which has the effect of sterilising the negative reserve these units could otherwise have provided. Therefore at times with larger response requirements, the negative reserve requirement is increased.

Timeseries

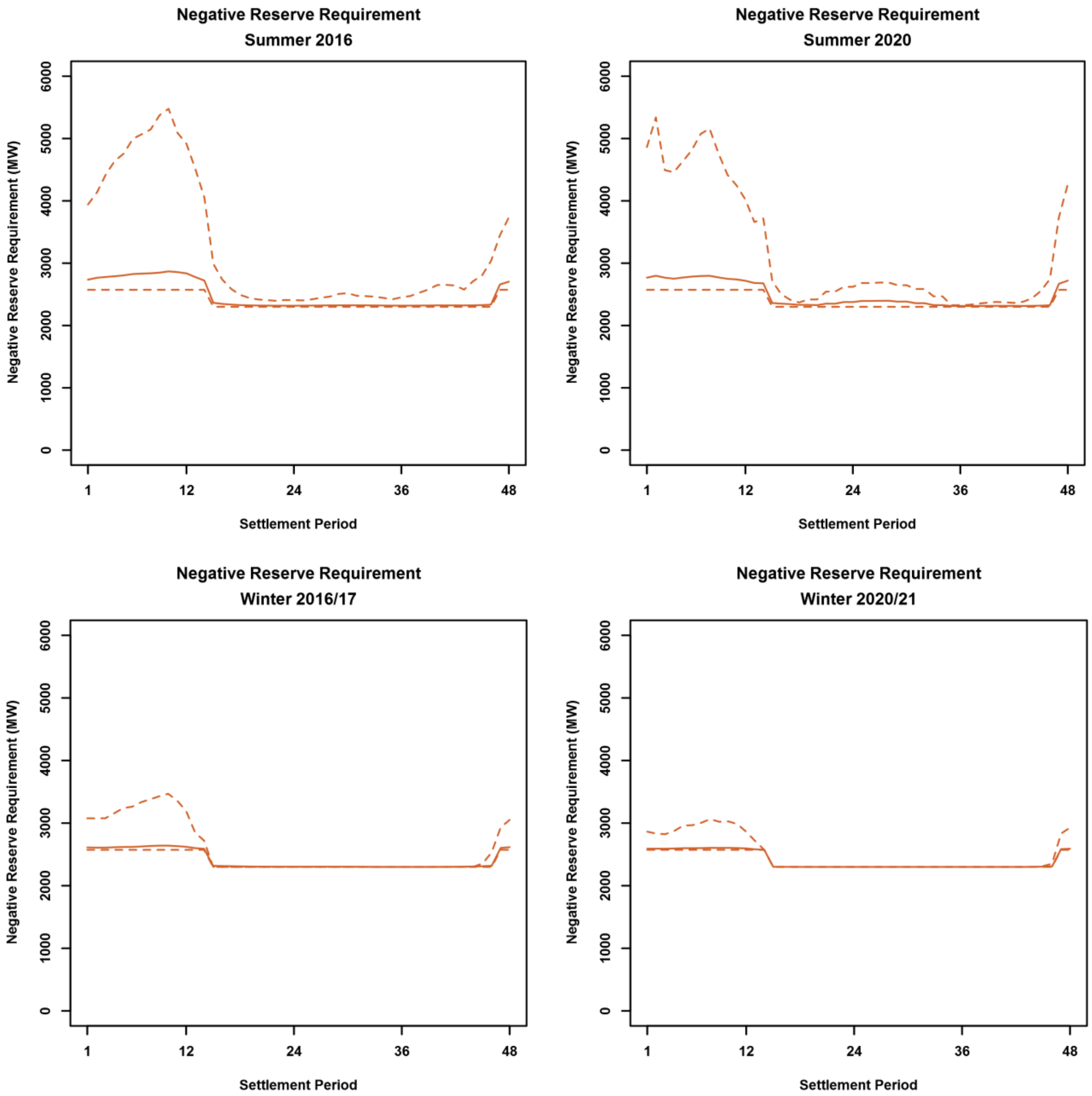
There is a wide variation in positive reserve requirements from day to day, the requirements over the month below show typical spreads of 2000 to 5000MW:



The change in requirements over short timescales is primarily due to the changes in the amount of negative reserve for high frequency response. As the amount of high frequency response required changes (due to low system inertia overnight), the amount of negative reserve for high frequency response increases.

Diurnal and Yearly Seasonality

The plots below present expected changes to both winter and summer negative reserve profiles from 2016/17 to 2020/21. The profiles assume that there is still a typical daily national demand shape on the transmission system, with peak and minimums demands consistent across all years:

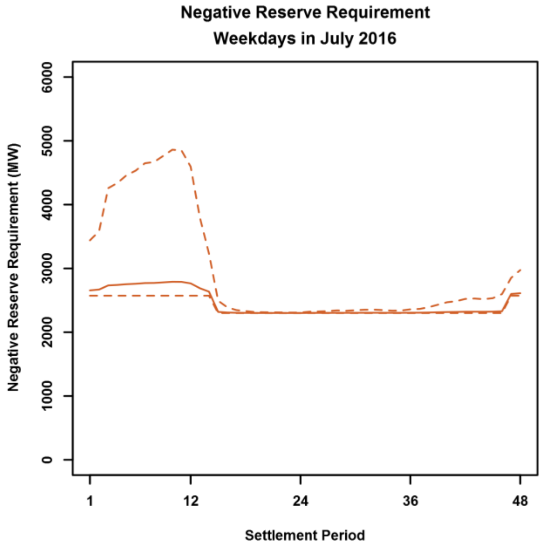


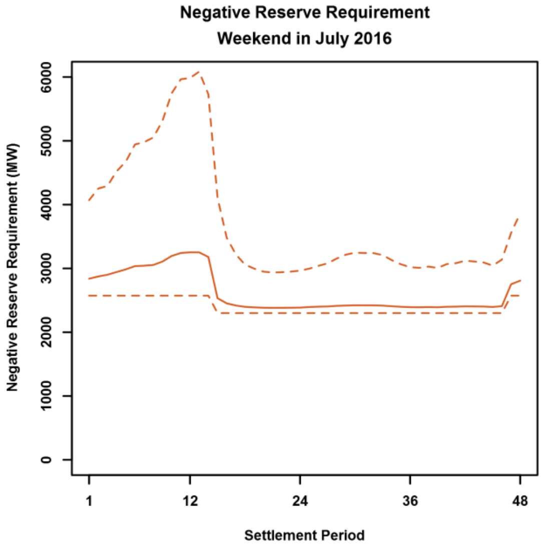
The dominant driver behind the variation in these requirements is the negative reserve for high frequency response. The drivers behind this are outlined in the high frequency response section.

Additional negative reserve will be held during the middle of the day to cover for periods when solar PV output is higher than is predicted. The additional requirement is proportional to the solar PV capacity, and easily seen in the summer 2020/21 graph.

Weekly Seasonality

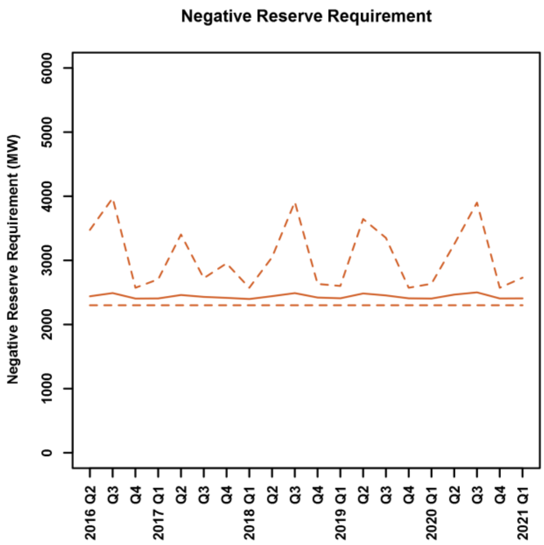
The negative reserve requirement is significantly different between weekdays and weekends. The higher negative reserve requirement overnight is brought about the need for more negative reserve for high frequency response. This is particularly applicable over summer weekends overnight, where the demand is lower and therefore the high response requirement is highest:





Overview

The graph below gives a broad overview of how much the envelope of negative reserve requirement changes over the next five years (due to the effects outlines above):



In summary, over the next five years, the maximum and minimum requirements for negative reserve are likely to remain similar, but there is significant volatility in the maximum required at any point during each year.

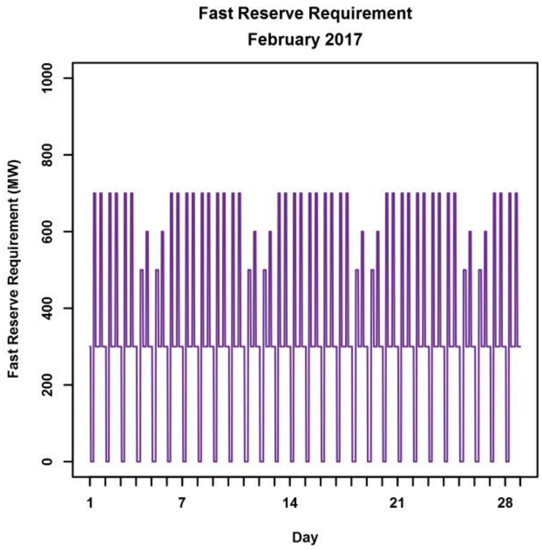
Fast Reserve

Fast reserve provides the rapid and reliable delivery of power through an increased output from generation or a reduction in consumption from demand sources, following receipt of an electronic despatch instruction from National Grid.

Fast reserve is used by control room engineers to manage three to five minute ahead forecast error. As demand is hardest to forecast (at these short leadtimes) when ramping, the requirement for fast reserve is highest during ramps.

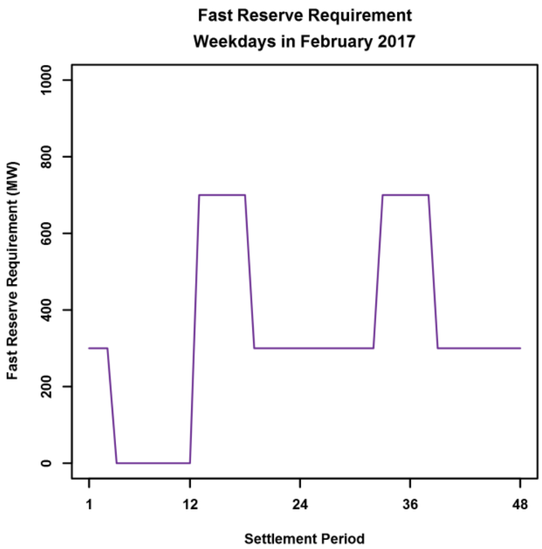
Timeseries

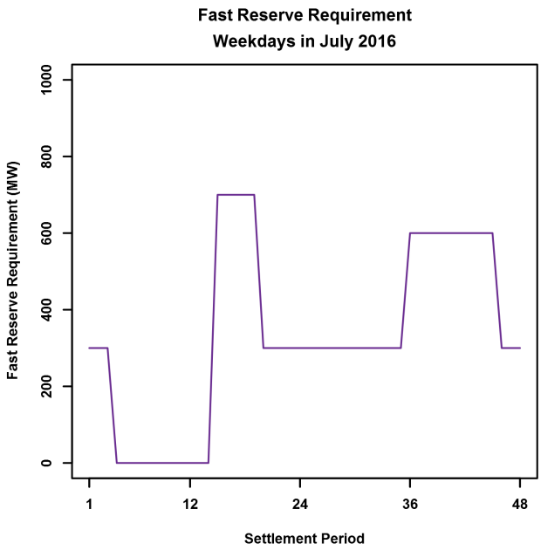
The requirement for Fast Reserve is characterised by a 300MW requirement during the day, rising to 700MW during demand ramps:



Diurnal and Yearly Seasonality

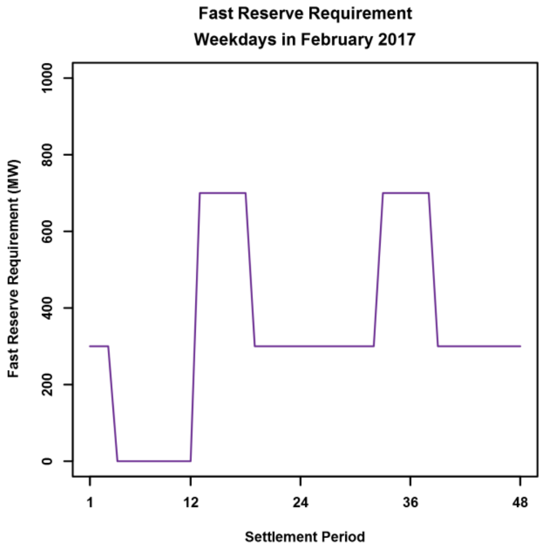
The plots below show how the daily profile of fast reserve requirement changes across the year. The driver for this change is the timing of the evening demand ramp. As the evening demand peak moves (with the time of sunset) over the year, the diurnal profile of the fast reserve requirement changes:

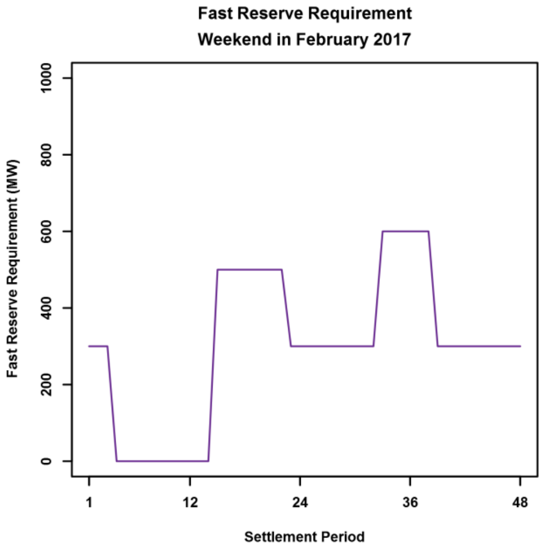




Weekly Seasonality

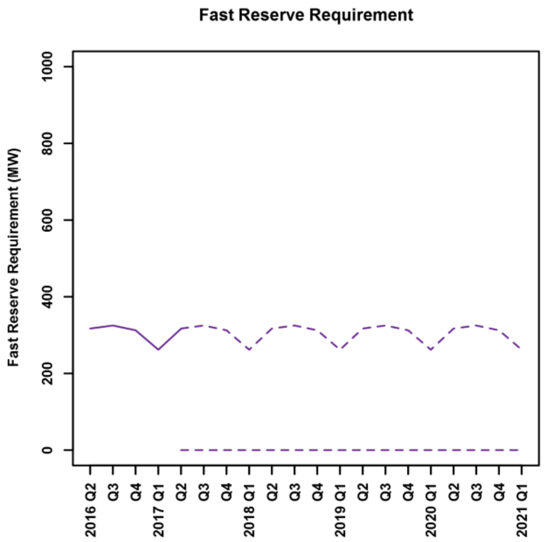
The requirement for fast reserve is lower over the weekend, and particularly so during the morning demand ramp:





Overview

Fast reserve is used by control room engineers to manage three to five minute ahead forecast error. When EBS[4] replaces the current control room systems, it will include the replacement of the forecasting system and the bid offer acceptance system. Following the operational commencement to EBS and assessment of its performance, the need for fast reserve *may* become zero, although it is also possible that the need for fast reserve will remain. These two possibilities are represented on the graph below as dotted lines:

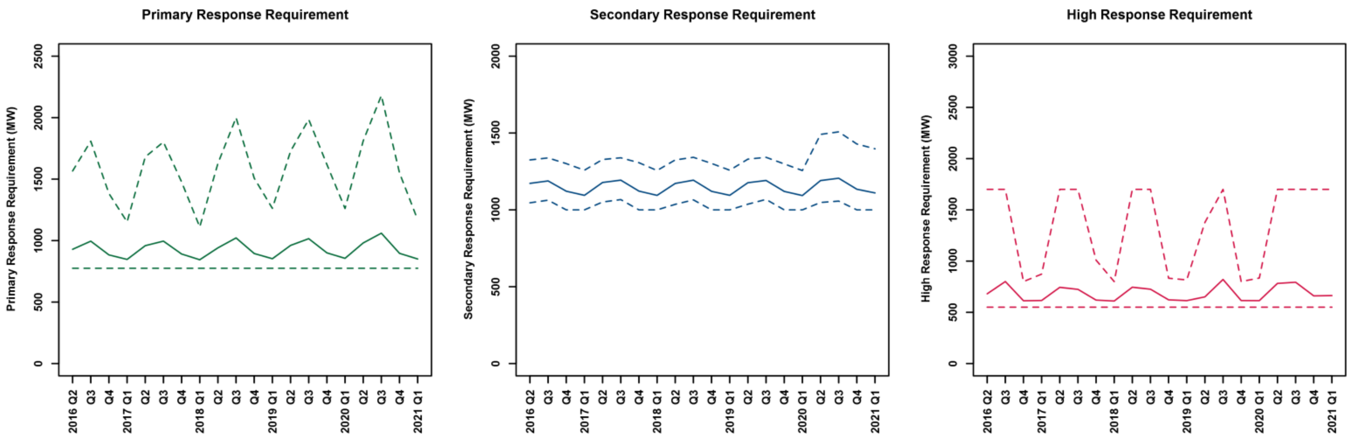


[4] Electricity Balancing System replaces the existing Balancing Mechanism system with a global best practice for balancing the real-time electricity supply and demand. The new system is due to be implemented in 2016.

Summary

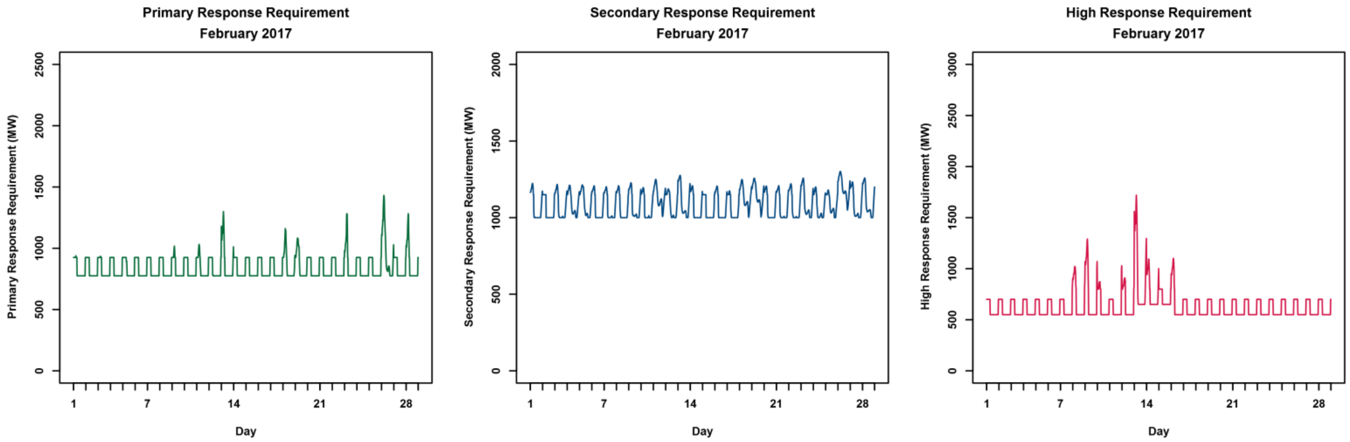
Response Requirements

The per-quarter requirements for reserve services over the next five years are as follows:



The main drivers of response requirements are inertia and secured loss size. Over the five years, inertia is slowly decreasing, which causes primary and high response requirements to increase. The requirements for all three response services increase during 2020/21 due to the increase of the potential generation and demand loss to 1400MW due to NSN link.

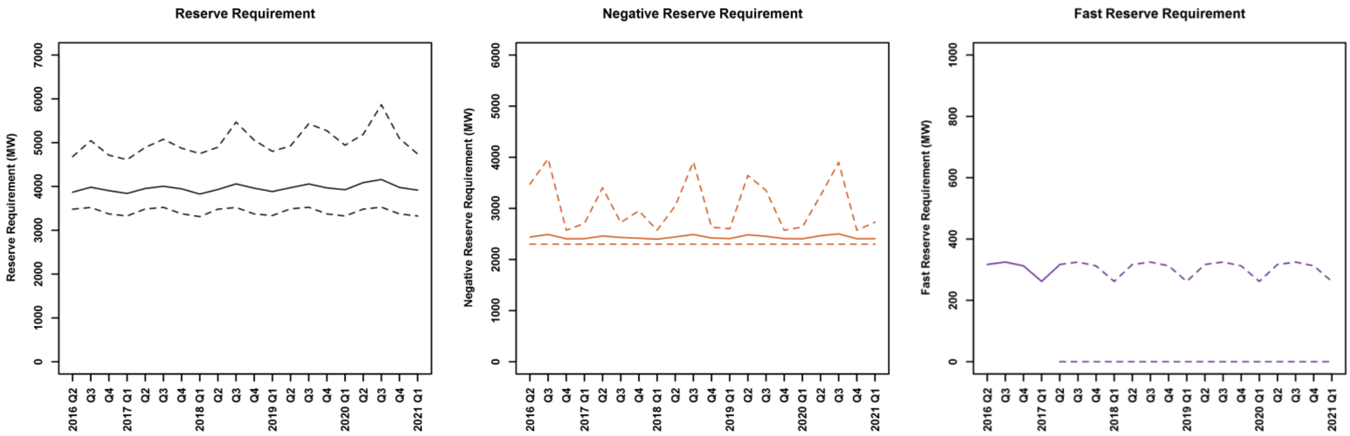
The day to day volatility in the requirements for response services are illustrated below:



From the graphs, the volatility in the requirement for primary and high response is much higher than the volatility in the requirement for secondary response.

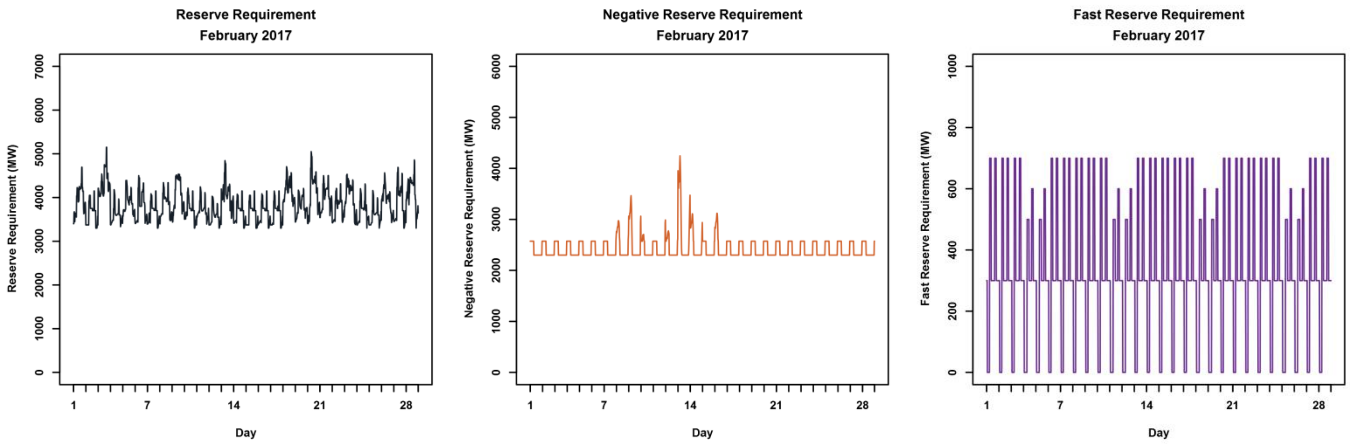
Reserve Requirements

The per-quarter requirements for response services over the next five years are as follows:



(Positive) reserve requirements slowly increase over the next five years, due mainly to the increase in the need for reserve for response and reserve for wind. The requirement for negative reserve is largely unchanged. Finally, the requirement for fast reserve will either remain the same as recent years, or alternately be zero depending on our experience of EBS.

The day to day volatility in the requirements for reserve services are illustrated below:



The day to day volatility in (positive) reserve requirement is largest of the three reserve services, and is mainly due to volatility in wind and solar output. The volatility in negative reserve requirement is driven by volatility in the reserve for response component (driven by the volatility in the high frequency response requirement). The fast reserve requirement has very low volatility once the seasonality in the requirement is understood.