Flexible Power

By Western Power Distribution

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Introduction

This document is intended to help potential participants understand the Flexible Power DSR (Demand Side Response) programmes.

Flexible Power's propositions have been designed with a view to being able to integrate within the existing flexibility marketplace. We have endeavoured to develop our Constraint Management Zone (CMZ) services to enable direct customers and aggregators to work within the rules set by other programmes with minimal conflict.

Contained within this document are explanations of the key principles of the services and an overview of the interactions between Flexible Power and the participants within the CMZ services. Payment calculation examples are also included.

The final objective of this document is to be an assistance note to the contract and act as a simple explanation to expedite the review and sign off process.

CMZ (Constraint Management Zones)

Flexible Power has developed three DSR services that each address different requirements on the distribution network. The services are called: Secure, Dynamic and Restore.

Secure

The Secure service is used to manage peak demand loading on the network and pre-emptively reduce network loading.

As these requirements are predictable, Secure requirements are declared each Thursday for the following week (commencing Monday). Payments consist of an Arming fee which is credited when the service is scheduled and a further utilisation payment awarded on delivery.

The week-ahead declarations are scheduled to allow customers to participate in alternative services when not required for the Secure service.

Dynamic

The Dynamic service has been developed to support the network in the event of specific fault conditions, often during maintenance work.

As the service is required following a network fault, it consists of an Availability and Utilisation fee. By accepting an Availability fee, participants are expected to be ready to respond to Utilisation calls within 15 minutes. Dynamic availability windows are declared each Thursday for the following week (commencing Monday).

The week-ahead declarations are scheduled to allow customers to participate in alternative services when not required for the Dynamic service.

Restore

The Restore service is intended to help with restoration following rare fault conditions. Such events are rare and offer no warning as they depend on failure of equipment. Under such circumstances, response can be used to reduce the stress on the network. This is the purpose of Restore.

As the requirement is inherently unpredictable, Restore is based on a premium ‘utilisation only’ service. This will reward response that aids network restoration, but will pay no arming or availability fees. Participants declared available for the Restore service will be expected to respond to any utilisation calls within 15 minutes and will receive an associated utilisation fee.

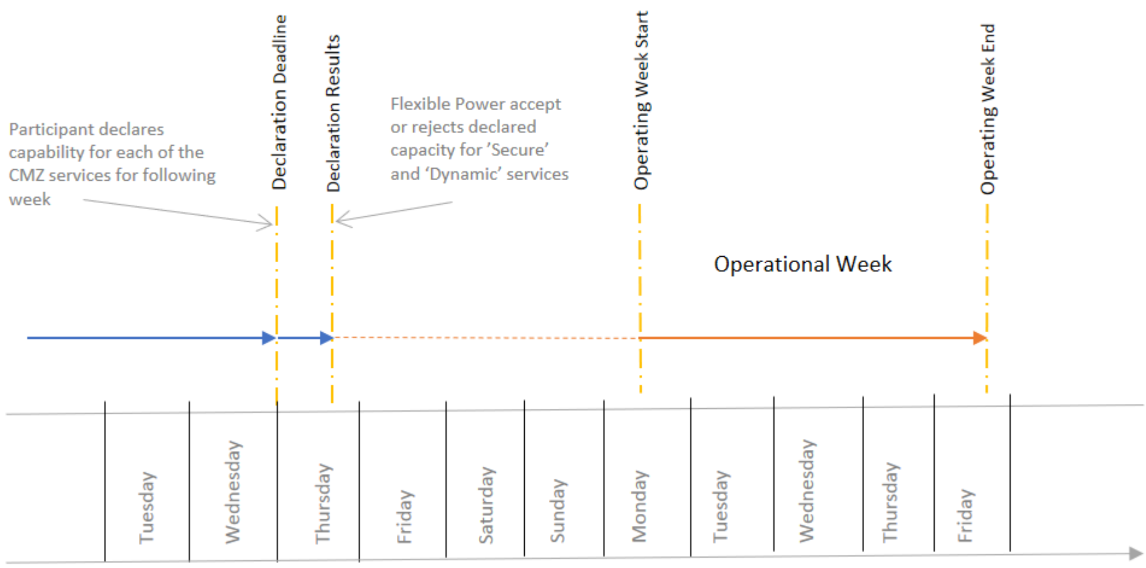
	Secure	Dynamic	Restore
Use case	Pre-fault mitigation	Post-fault recovery (often under planned outages)	Post-fault network restoration
Advanced payment	Yes, an arming payment for the accepted availability time £125/MW/h	Yes, an availability payment for the accepted availability time £5/MW/h	No
Utilisation payment	£175/MWh	£300/MWh	£600/MWh
Availability declarations	By midnight every Wednesday for the following week (Mon-Sun)		
Availability acceptance	By noon every Thursday for the following week (Mon-Sun)		
Dispatch Notice	Week Ahead, on acceptance of availability	15 minutes ahead of requirement	15 Minutes ahead of requirement

Customer Availability / Declarations

Flexible Power have designed the CMZ services to interact with existing DSR services and establish any requirements ahead of the declaration deadlines for National Grid balancing services.

Each contracted participant will have access to the customer portal (www.flexiblepowerwpd.co.uk) where they can update the available capacity that they can offer for each CMZ. Different capacities can be declared for each of the three CMZ service types (Secure / Dynamic / Restore). This can be a static declaration or can be altered each week with whatever capacity is stated at the time of the declaration cut off at midnight on Wednesday. The payment mechanics have been designed to encourage participants to carefully consider the capacity that they declare to be achievable as under performance will result in reduction of payments as explained in the following sections.

WPD control engineers then carry out analysis for the following week and notify Flexible Power of any Secure or Dynamic service requirements, which is then relayed to participants as declarations by midday on Thursday for service delivery commencing the following Monday. If Flexible Power doesn't declare any requirements then participants can make their assets available to other DSR schemes. All capacity declared for the Restore service is automatically accepted.



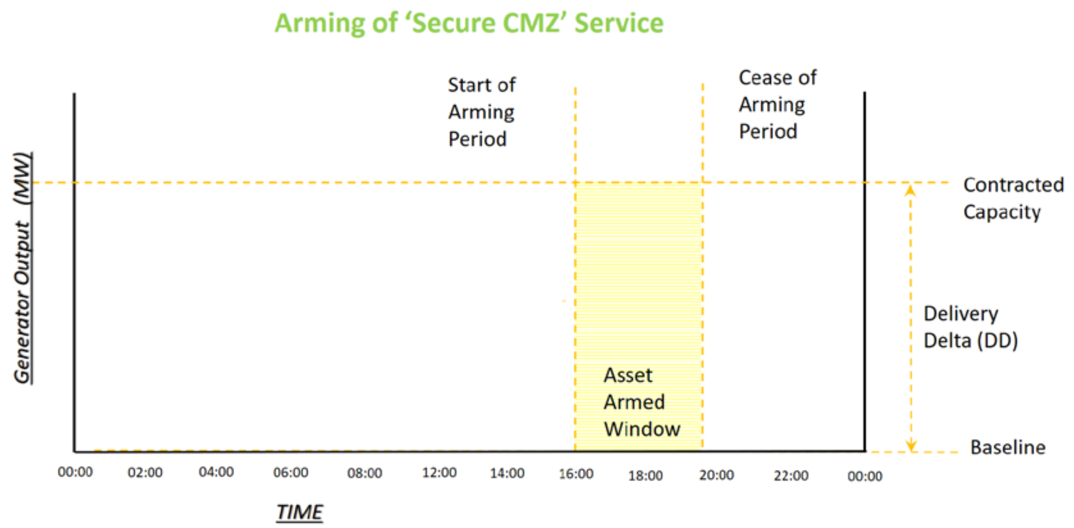
Secure CMZ service

For this procurement payments are set for each CMZ. These are split into two payment elements that we have called Arming and Utilisation.

Secure Arming

The term Arming has been intentionally been used so as to avoid confusion with Availability that is paid for in the Dynamic service. The reason for this is to reflect the greater certainty in the forecasting for the participating assets to run. The Arming fee relates to a payment made to participants to be in a state of readiness having been scheduled to provide DSR for the entire duration of the Armed period. The Arming Windows will be identified on the basis of a week ahead forecast that will typically be identified by midday on the preceding Thursday.

At the point of notification on the Thursday the arming fee is awarded in full to the participants who are declared available to offer service. In the event that running requirements reduce, the site /group will be given notification that they don't need to run, but will retain the Arming fee. The 'Arming Fee' should reflect the majority of the profit aspect of the total CMZ payment.



The payment is based on a rate that is broken into ½ hourly increments for the duration of the arming window. The payments can be reduced should the site / group be unable to meet its expected delivery during the window due to technical or operational reasons. Unlike DSR for balancing services for National Grid, the delivery requirements for CMZ don't require an immediate change in behaviour to reduce demand on the network based on a real-time baseline. For many participants the Secure CMZ service may be compatible with other programmes, as long as the site / group can maintain the DSR action for the duration of the Arming Window. Participation therefore doesn't sterilise the participant's asset for exclusive use within CMZ.

When a site is given an arming instruction on the Thursday, the assumption is then set that Utilisation of the DSR capacity will be provided for the entirety of the Arming Window. The site therefore has the option to schedule assets to operate during arming windows and await a notice to stand down in the event that conditions change. Flexible Power can also provide an automatic start notification 15 minutes prior to the commencement of an active Arming Window.

Secure Utilisation

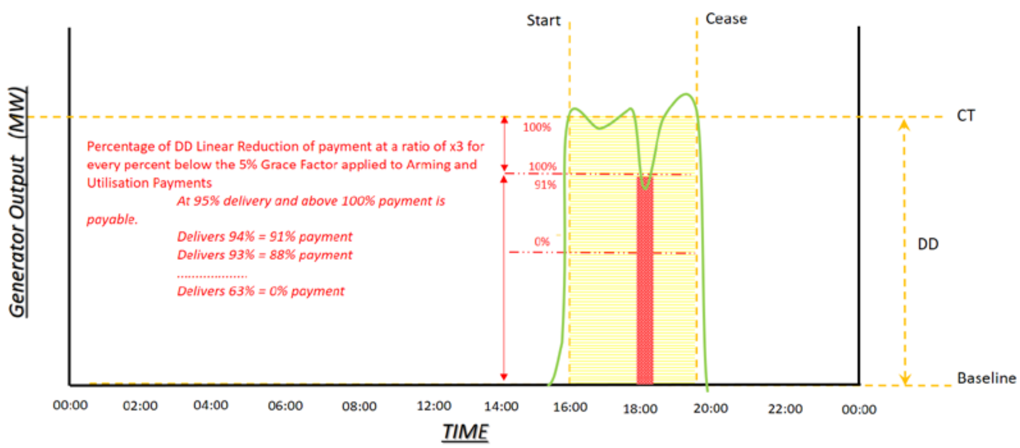
The utilisation payment is intended to reflect the approximate operating cost of generating assets that are commonly used to provide the DSR response. The purpose of this is to provide certainty to the participant that after receiving an Arming instruction they are guaranteed to receive their financial benefit even in the event that the site / group isn't dispatched during the arming window.

The utilisation element relates specifically to the period between the start and cease of a 'CMZ Secure' event. Participants are expected to achieve delivery of the agreed demand reduction by the start of an event. It is expected that a site should be delivering 95% or above of it expected Delivery Delta (DD). A site / group can opt to start based on the schedule provided when armed the previous week, alternatively Flexible Power can send a dispatch signal 15 minutes in advance of the event start time. Slower responding assets can participate in the Secure services due to the advance notice provided through the arming principle, as long as they can achieve the contracted capacity by the event start time. Late delivery or under performance will be automatically penalised through the design of the payment mechanism.

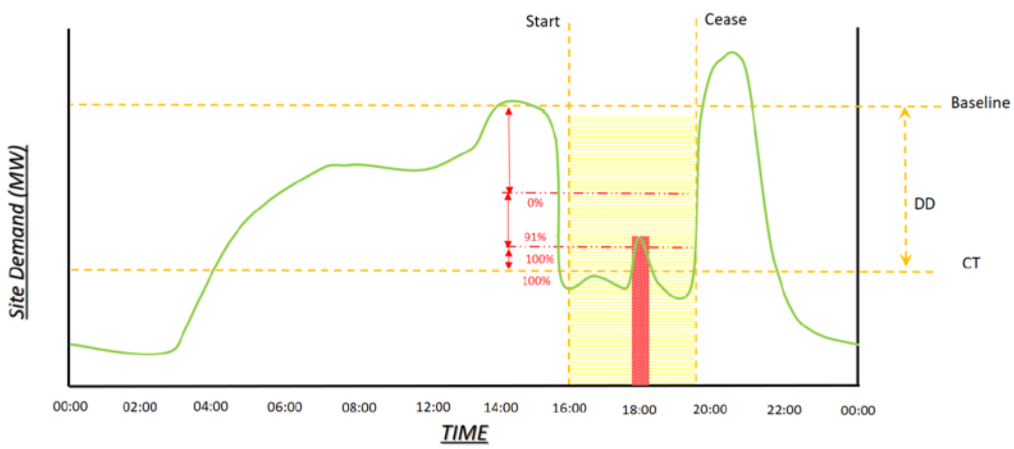
The (DD) is calculated from a baseline that is designed around the average demand calculated from the previous months site demand or asset use, this is explained in greater detail later in the document. For a reduction site this can be calculated using the site data collected at the settlement metering. Settlement meters do not provide sufficient granularity for the service operation, and therefore an acceptable metering device capable of recording on a minute by minute basis will be necessary to measure event delivery. For generation sites there is the option to measure impact either using the same metering arrangement as reduction sites, or the generator's own meter if it has minute by minute capabilities. Generators that are the primary source of supply such as CHP will need to be assessed for the most appropriate method so that only the flexible element of their operating capability is declared.

Following the event start time, the delivery of a site will be assessed at 1 min intervals against the agreed delivery capacity. Each minute interval is then subjected to a performance calculation as follows.

Utilisation of 'Secure' CMZ – Generation Site



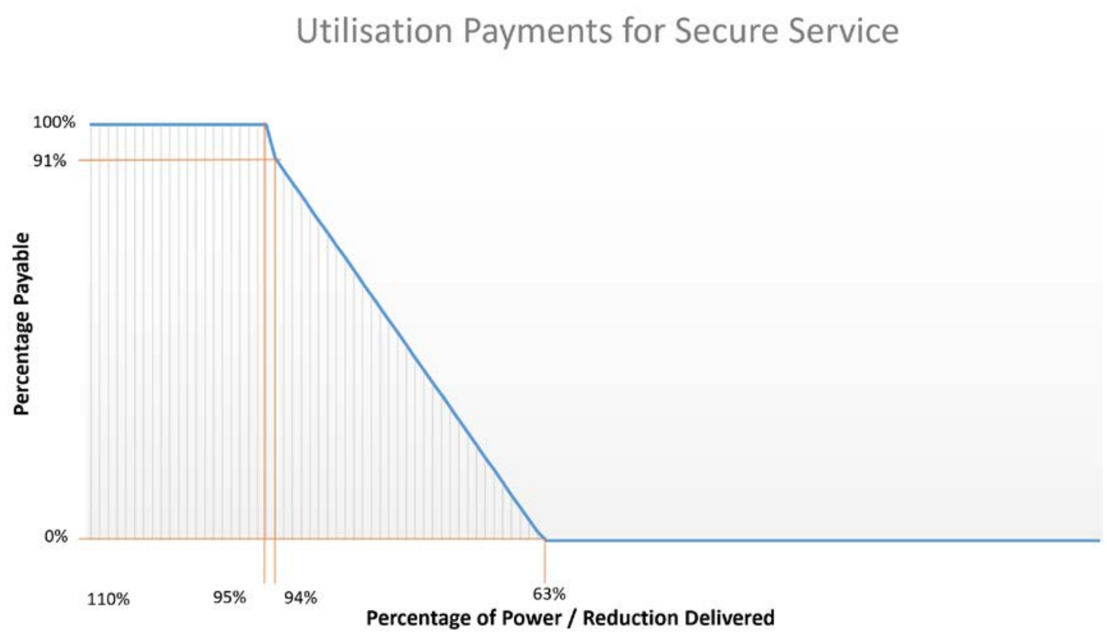
Utilisation of 'Secure' CMZ – Reduction Site



Delivery of 95% or above is regarded as a 100% for each minute interval, but capped at 100%. If delivery falls below the 95% threshold then a ratchet mechanism will reduce the utilisation earnings by a multiplication factor of (x 3). Each minute interval is regarded as a discrete calculation with the total utilisation payment for an event equalling the sum of all the interval payments.

It is not possible to make up a shortfall in the utilisation payments from one measured minute interval by over delivering in another. Any over delivery will however count towards the total volume delivered for that whole event, which is also measured for the purpose of 'Monthly Volume Reconciliation'. This is detailed in the next section of the document.

This payment principle that is applied for each individual minute measured during the utilisation period is shown on the diagram below.

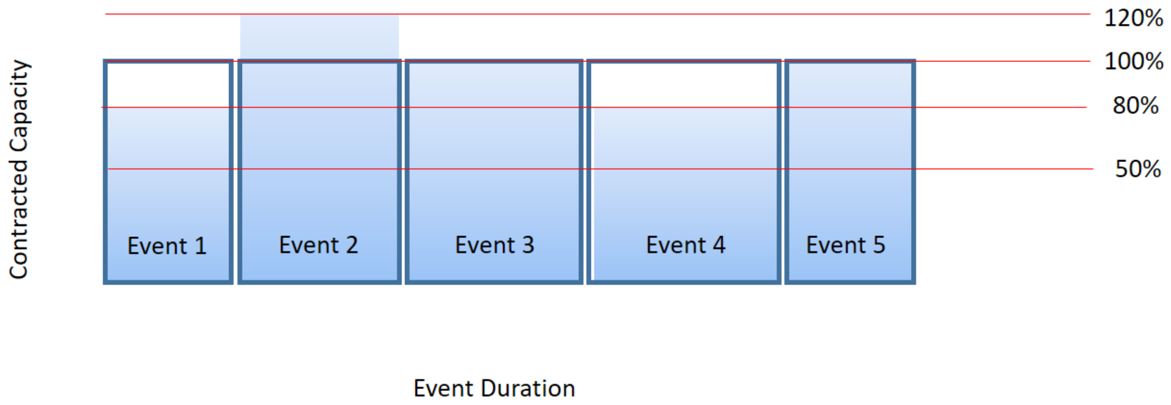


Secure Monthly Volume Reconciliation

The purpose of the monthly Volume Reconciliation is a mechanism to recover arming payments, if a site fails to deliver the expected capacity over the duration of the utilisation periods.

Each event will have a theoretic delivery volume of electricity which relates directly to the utilisation and is based upon delivery of 100% without any grace factor or ratchet, for the duration of the event. Any shortfall on the delivered capacity percentage for each event is then combined to establish an average percentage for all events within a month. This is demonstrated in the diagram below, where the blue shading represents the energy delivered and the box for each event represents 100% of the expected volume. Unlike the utilisation calculation, each discrete 1 minute interval is permitted to exceed 100% but the total event delivery cannot exceed 100%.

In a similar principle to that of measuring utilisation in discrete 1 minute intervals, each event is capped at a maximum volume of 100%. This means it is not possible to make up a shortfall in total volume delivered in one event by over delivering in another.



Based on the five example events above, the site achieved a total monthly volume equivalent to 92% based on the event average performance.

$$\frac{(80\%+100\%+100\%+80\%+100\%)}{5} = \mathbf{92\%}$$

The Monthly Volume Reconciliation does not affect utilisation payments and is only applied to the Gross Monthly Arming Fees. Based on this performance the total Arming Payments accrued over the month will be multiplied by 92% to calculate the final settlement payable.

Dynamic CMZ service

The Dynamic service is reactive to network faults and therefore cannot be scheduled ahead of need in order to manage a constraint event. As such we have adopted the more commonly recognised Availability payment mechanism. The Availability windows are expected to be significantly longer than the Arming windows in the Secure service extending to as much as 24hr during the working week. At any time during the availability period Flexible Power could be requested by WPD's control engineers to dispatch the declared capacity with a 15 minute notice period.

Dynamic Availability

The Availability fee relates to a payment accrued by participants to be in a state of readiness, when they may be required. The primary difference with the payment mechanics of Availability is that it is not awarded in advance as with Arming, and is accrued following each ½ hour interval of the Availability window. If at any stage that the participant was to be unable to deliver the majority of their declared capacity during a window they should declare themselves unavailable. As with the Secure service, the declarations are to be completed by midnight on Wednesday, and can include capacity, the length of window for which it is available and minimum / maximum utilisation period.

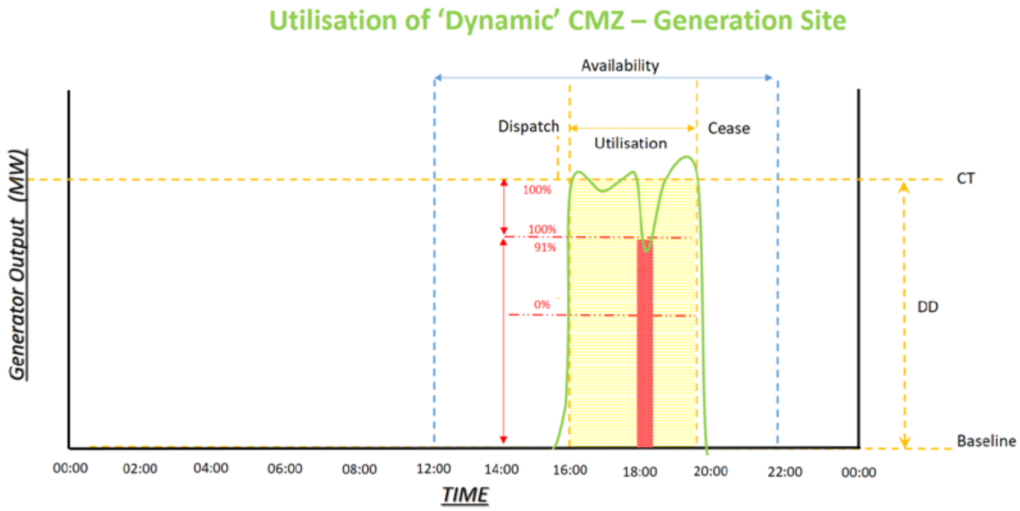
The payment is based on a rate that is broken into ½ hourly periods for the duration of the Availability window. If the participant is called upon to dispatch but the site / group is unable to meet its expected delivery during the window a similar reconciliation based on monthly delivered volume is used to reduce the availability element of the income. The structure of the payment reconciliations is the same as that used for the secure service and detailed later in this section of the document. As with the Secure service, the delivery requirements don't require an immediate delta reduction in demand. For many participants, the service may be compatible with other programmes with one of the few prerequisites being the site / group can maintain the DSR action for the duration that was specified in their weekly declaration. Participation therefore doesn't sterilise the participant's asset for exclusive use within CMZ. It is more likely that this service will be required throughout the year and not just in the winter when peak demand periods are most common.

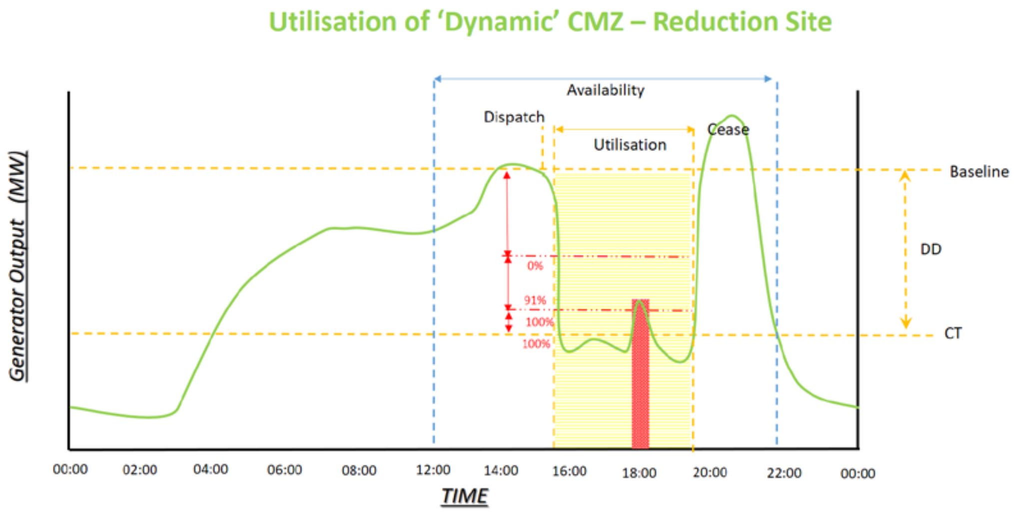
Dynamic Utilisation

The Dynamic utilisation payment is set at a different level than that offered by Secure utilisation which reflects the difference in certainty, duration and response time. As outlined in the previous section, this is due to the lower likelihood of it actually being required and the extended period over which it could be called. If it is dispatched, it is likely that it will run for a duration of several hours, potentially up to the maximum set by the participants.

The utilisation element relates specifically to the period between the start and cease of a Dynamic event. Participants are expected to achieve delivery of the agreed demand reduction within 15 minutes of receiving their dispatch notice. It is expected that a site / group should be delivering 95% or above of it expected Delivery Delta (DD).

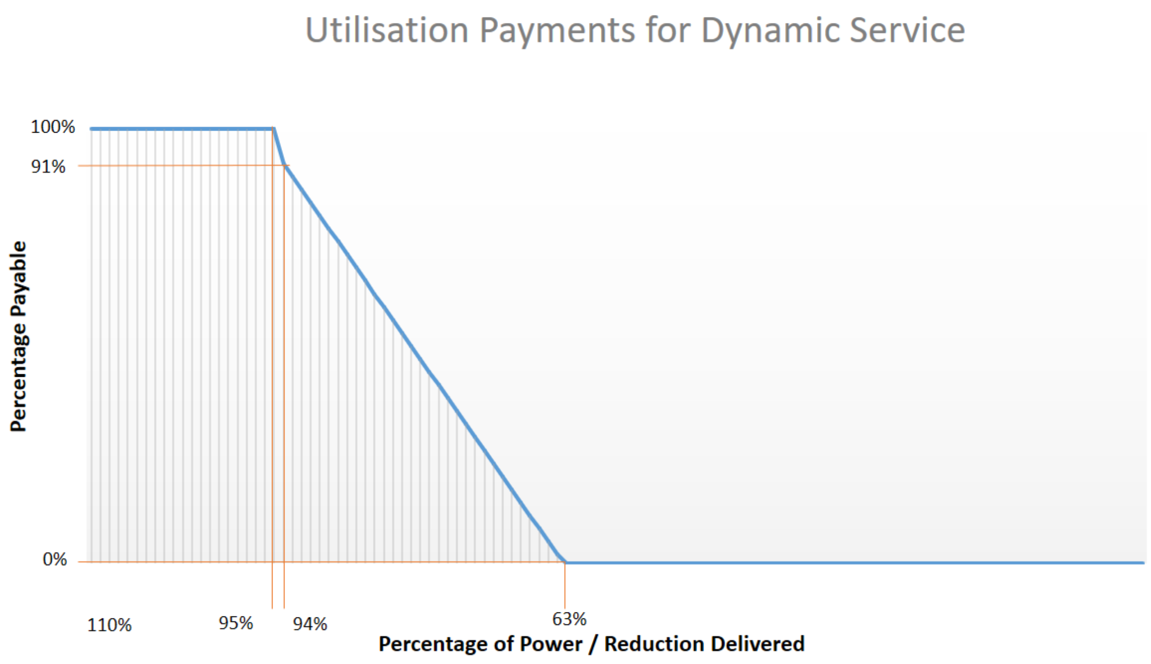
The (DD) is difference between the baseline that is calculated using the site consumption or generator output during the previous month, and the weekly declaration made by the participant. Details of the baseline methodology are covered later in the document.





Delivery of 95% or above is regarded as a 100% for each one minute interval throughout the utilisation event, but capped at 100%. If delivery falls below the 95% threshold then a ratchet mechanism will reduce the utilisation earnings by a multiplication factor of 3. Each minute interval is regarded as a discrete calculation with the total utilisation payment for an event equalling the sum of all the interval payments. It is not possible to make up a shortfall in utilisation from one measured minute interval by over delivering in another. Any over delivery will however count towards the total volume during the event which is also measured similarly to the Secure service for the purpose of Monthly Volume Reconciliation. This is detailed in the next section of the document.

This payment principle for each individual minute measured during the Dynamic utilisation period is the same as Secure in order to avoid unnecessary complication. It is shown on the diagram below.

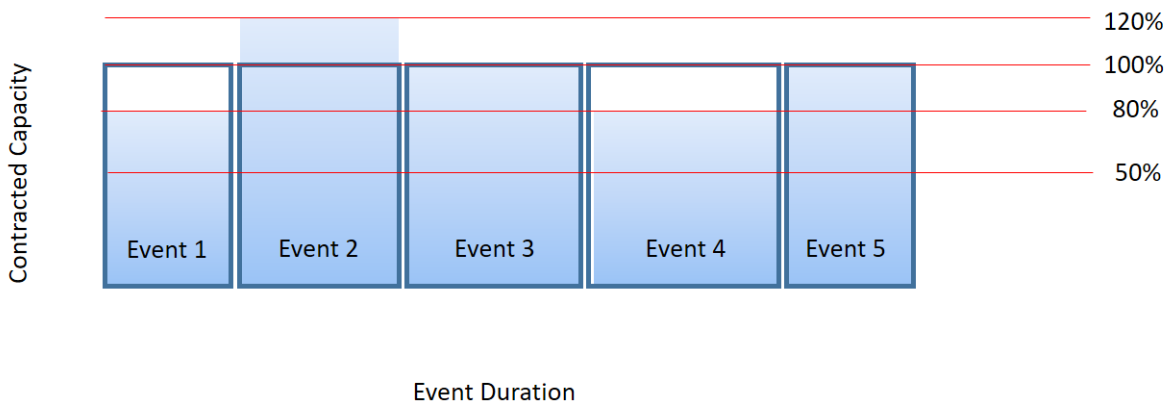


Dynamic Monthly Volume Reconciliation

The purpose of the Monthly Volume Reconciliation is a mechanism to recover availability payments in the event that a site fails to deliver the capacity it declared it would over the duration of the utilisation periods.

Each event will have a theoretic delivery volume of electricity and is based upon delivery of 100% of the declared capacity for the duration between start and cease. Any shortfall on the delivered capacity percentage for each event is then calculated as an average for all events within a month. This is demonstrated in the diagram below, where the blue shading represents the energy delivered and the box for each event represents 100%. Unlike the utilisation calculation, each minute interval is permitted to exceed 100% but the total event delivery cannot exceed 100%.

It is not possible to make up a shortfall in total volume delivered in one event by over delivering in another.



Based on the five example events above, the site achieved a total monthly volume equivalent to 92% based on the event average performance.

$$\frac{(80\%+100\%+100\%+80\%+100\%)}{5} = 92\%$$

The Monthly Volume Reconciliation does not affect utilisation payments and is only applied to the Gross Monthly Availability Fees. Based on this performance the total Availability Payments accrued over the month will be multiplied by 92% to calculate the final settlement payable.

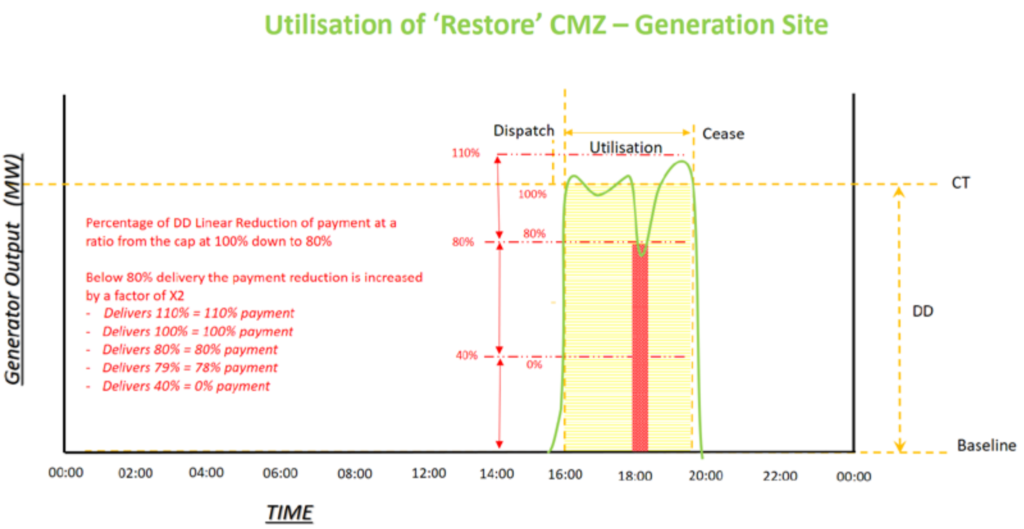
Restore CMZ service

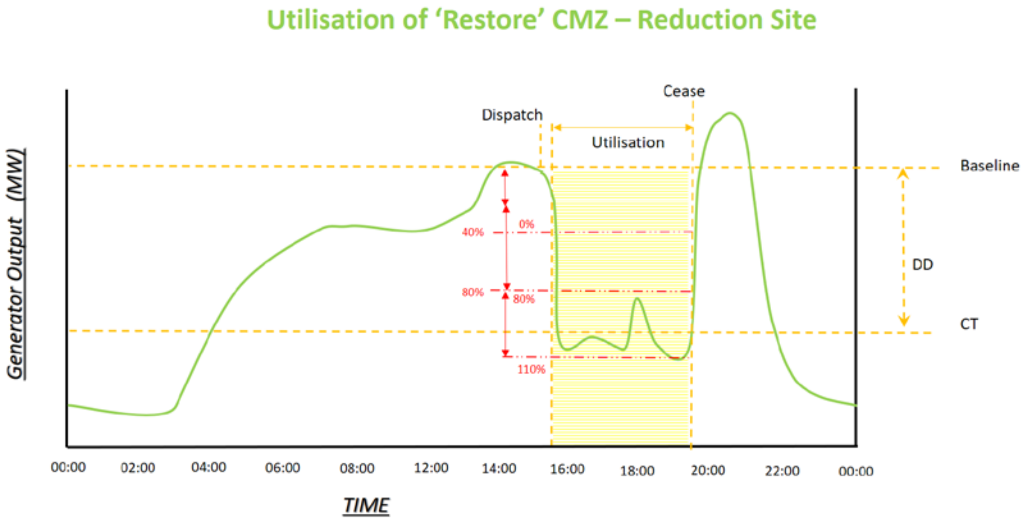
The Restore service requirement is very unlikely to ever be predictable and therefore we have not built in either an Arming or Availability mechanism.

The Restore service has been developed on the principle of paying a premium utilisation fee to participants that acknowledges the potential value of their contribution to the restoration of 'normal' network conditions. This premium fee is expected to help compensate for disruption to other economic activities that results from being called upon and reward for the contribution towards supporting the network until a fault is resolved.

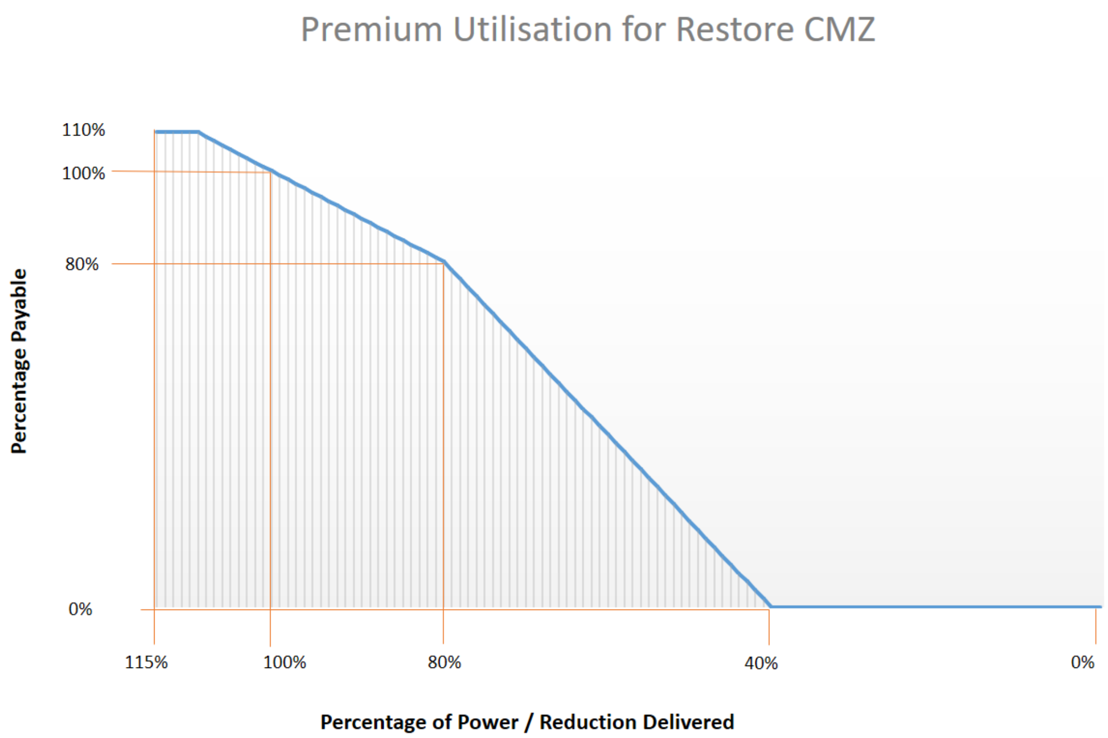
Restore Premium Utilisation

The premium utilisation is still subject to a capacity declaration determined by the value that the participant has provided within the web portal, prior to the cut-off at midnight, the preceding Wednesday. This can be done independently of declarations for the previous services, including the different capacity. It is still important for Flexible Power to have a reasonable indication of how much DSR response it can provide at any given time to assist WPD's operational planning for abnormal events. As there is no retention payment, Restore CMZ employs a less punitive utilisation payment mechanism. This is outlined below.





As with the previous payment mechanisms, it is based on a calculation that is applied to each one-minute interval during the event. The relationship between the expected (DD) and actual delivery in this instance is more linear. At 80% delivery, a payment of 80% is accrued for that period. This linear relationship continues up to a maximum of 110% allowing for a capped over delivery. For each percentile that falls below 80% a ratchet factor that doubles the reduction meaning 79% performance will receive 78% payment. This double rate of reduction continues this principle on a linear path so the participant would only get 2% payment at 41% and zero for 40% and below. These principles are demonstrated in the diagram below.



Baseline Methodology

The Flexible Power method of calculating the baseline is intended to achieve a number of objectives:

- Vary monthly to reflect operational trends by participants
- Reward participants for the largest impact they can offer
    - Avoid penalising for calling at a time when demand isn't high
- Target delivery to be fixed value
    - Easy for participants to know what is expected
    - Simple to forecast for declarations

In order to satisfy the above criteria a system has been created where the participant will set their DSR capacity themselves, against a monthly baseline. This is measured slightly differently for generators and demand reduction sites.

Both types of participant have the opportunity to vary their declared capacity each week if they wish, and would be advised to review each month when a new baseline is calculated.

Demand Reduction

The point of measurement on a demand reduction site will typically be at the point of supply and potentially located alongside the current fiscal meter. The normal settlement meter is likely to be a half hourly meter and therefore won't provide the necessary granularity.

We would like the site to establish its lowest level of demand that it can reliably reduce its demand to at any point during the week. The site can also set other parameters including maximum and minimum duration of an individual event along with recovery times. This ensures that the site determines what it is able and willing to do in the event of being called by Flexible Power based on its own capabilities.

For the purposes of working out what a participant should be paid is shown earlier in the document and requires a 'Delivery Delta' so as to calculate the performance payments. The DD is measured from a baseline that we would also like to make a monthly constant but is not based upon a single peak as this could inadvertently reward for increased consumption.

The system therefore focuses on establishing an average demand over a series of period of weeks, but taken from period of the day where demand is typically higher than average. This should ensure that the DD used to calculate payments should be consistently greater than if we were to use data across the whole day, which in turns helps ensure a more generous arrangement for participants.

The data used for the baseline will be an excerpt from the first three full weeks of the month, between 3pm and 8pm, giving a sample over a total of 75 hours.

The consumption during the five hour period for each day is totalled and divided by the 75 to establish the monthly average demand which then becomes the baseline for the following month. The nature of the CMZ service is such that we would not expect there to be a protracted requirement for repeated months that would result in use of the service being required again so soon as to be distort payments in months following use. However if this were ever to occur a discretionary decision will ensure that the participant is not unfairly impacted.

Generation increase

The point of measurement on a generation site is advised to be the output terminals of the generator. This is common within other DSR programmes and Flexible Power are keen to avoid deviating from such standards and as a result requiring additional investment from existing DSR providers. In keeping with this, it is also expected that the metering used for the purpose of other DSR services will also be able to collect and provide data at 1 minute intervals.

Generation can take several forms, and for DSR we are not seeking ‘intermittent’ generators such as solar and wind which can’t be dispatched reliably at the times we may require it. ‘Non-intermittent’ generation may fall into two general categories. The first is ‘stand-by’ generation which will typically be in a ‘holding’ state where it is rarely used, and is only called upon briefly during emergencies, to test or within a DSR programme. In instances such as this it is practical to agree that the baseline should be set at zero.

If a battery or Combined Heat and Power (CHP) installation is being used then there is an expectation that it will be in regular use. Therefore we would adopt an alternative methodology by measuring average output for a baseline and calculate the DD as ability to increase

Payment Calculations and Examples

This final section of the document details the payment calculations for sites participating in DSR services with detailed explanations and examples where appropriate. For each of the three services, there are several payment calculation variables that are similar: we maintain a consistent naming scheme to avoid confusion, but note that they can be (and are) different for each service. We provide the suggested values at the end of each section

Secure Service

A single payment is given for availability of a site during an arming window, and for delivery during a constraint event during an arming window. We have defined settlement periods, SP_u and SP_a which correspond to the fraction of an hour for utilisation and arming windows. In our case, the utilisation settlement period is 1 minute, and arming window settlement period is 30 minutes i.e. $SP_u = \frac{1}{60}$ and $SP_a = 0.5$.

For each site, we have three constant values:

- A contracted capacity (CC_s), given in MW, which is generation or load reduction that a site must be available to perform during a window, and must deliver during an event.
- A utilisation cost (UC_s) , which is the payment per MWh delivery by the site
- An arming fee (AF_s) , which is the payment per hour of arming availability, not per MWh.

Payments are calculated on a month-by-month basis. The two main calculations in this document determine the utilisation and arming payments due to a site for a given month.

For each month, m, we have a list of arming windows and a list of *Secure* events, which we will write as AW_m and E_m. The top-level calculations will loop through these lists, but the bulk of the work is performed for an individual arming window and an individual *Secure* event.

Secure Utilisation Payments

For a given site (s), utilisation payments are calculated event (e). Each event has a start time (ST_e) and a finish time (FT_e) such that $ST_e < FT_e$.

The *Secure* utilisation payment is given by:

$$U_{s,e} = \sum_{j=ST_e}^{FT_e} CC_s \,.\, UC_s \,.\, SP \,.\, PP(CC_s, AD_{s,j})$$

Where:

- $U_{s,e}$ is the constraint management utilisation payment for site (s) during each event (e)
- $\sum_{j=ST_e}^{FT_e}$ sums over the time segments in the event.
- CC_s, UC_s, and SP are the contracted capacity, utilisation cost and settlement period of the site for *Secure*, as defined above.
- The function PP, defined below, is the *Payment Proportion* and works out what fraction of the full price is due to the site for every settlement period based on contracted capacity and actual delivery
- $AD_{s,j}$ is the actual, metered delivery of the site s for time segment j. In the payment calculations, there is no difference between generator sites and demand reduction sites, since this value is the reported value

For a given site (s), utilisation payments are calculated per-Event (e). Similarly to availability payments, each event has a start time (ST_e) and a finish time (FT_e) such that $ST_e < FT_e$.

$$U_{s,e} = \sum_{j=ST_e}^{FT_e} CC_s \,.\, UC_s \,.\, SP_u \,.\, PP(CC_s, AD_{s,j})$$

Where:

- $U_{s,e}$ is the utilisation payment for site (s) during *Dynamic* event (e)
- $\sum_{j=ST_e}^{F_e}$ sums over the time segments in the event.
- CC_s, UC_s, and SP_u are the contracted capacity, utilisation cost and settlement period of the site, as defined above.

- The function PP, defined below, is the *Payment Proportion* and works out what fraction of the full price is due to the site for every settlement period.
- $AD_{s,j}$ is the actual, metered delivery of the site *s* for time segment j. In the payment calculations, there is no difference between generator sites and demand reduction sites, since this value is the 'reported to grid' value.

Secure Payment Proportion

A site is awarded full payment for greater than or equal to perfect performance and to performance within a margin of error for under-delivery, known as the *grace factor* (GF). If the site does not meet this expectation, they may be penalised, based on the rules defined below.

We define the *Delivery Proportion* $(DP_{s,j})$ as the ratio of actual delivery to contracted capacity. This ratio is a value that represents a percentage. It is given as follows:

$$DP_{s,j} = Round(\frac{AD_{s,j}}{CC_s})$$

where the raw proportion is rounded to two significant figures to ensure it represents a whole percentage.

The Grace Factor determines the acceptable under-delivery for a site. Then for every % point under that level, a fixed proportion (called the penalization multiplier, PM) of a site's due payment is rescinded. Over-delivery is paid at contracted capacity.

Thus, the Payment Proportion is a value between 0 and 1 (or 0 and 100%). The calculation is a little complex as it enforces the 0 and 1 constraints directly:

1) $PP_{s,j} = 1, if\ DP_{s,j} \geq (1 - GF)$

2) $PP_{s,j} = Max(0,\ 1 - GF - PM\ .[1 - GF - DP_{s,j}]), if\ DP_{s,j} < (1 - GF)$

Monthly Utilisation Payments

Similarly, we calculate the utilisation payment due for a given site in a month as the sum of the individual *Secure* event utilisation payments:

$$U_{s,m} = (\sum_{e \epsilon M} U_{s,e})$$

Arming Window Availability Payments

The availability payments for an arming window are paid based on availability for each settlement period. We assume the following values:

- ST_{aw} and FT_{aw} as the start and finish time of the arming window
- $SA_{s,j}$ is the site availability for that settlement period in an arming window
- $AF_{s,aw}$ is the arming fee for that site and arming window on a per-settlement period basis.

Then, the *Arming Window Payment* for a site and arming window is the product of the availability for that arming window and the Arming Fee for that period:

$$AWP_{s,aw} = \left(\sum_{j=ST_{aw}}^{FT_{aw}} AF_{s,aw} \,.\, SP_{aw} . SA_{s,j} \right)$$

For example, given a window that is 4 periods long and a site that is recorded as available for the first two i.e. [1,1,0,0], and an AF of £30 per settlement period, then the payment will be 30*1 + 30*1 + 30* 0 + 30*0 = £60.

Secure Service Monthly Reconciliation

The arming window availability payments are also subject to a monthly reconciliation, based on utilisation performance.

The *Secure* Event Delivery Proportion $(EDP_{s,m})$ for a site for a given month is:

$$EDP_{s,m} = \frac{\sum_{e \,\epsilon\, Em} Min(1, EP_{s,e})}{\#E_m}$$

i.e. the capped proportion of average deliveries for a participant in a given month.

- $e \,\epsilon\, E_m$ is every *Secure* event in the set of *Secure* events for the month m.
- $\#E_m$ is the number of *Secure* events in the month
- $Min(1, EP_{s,e})$ caps the *Secure* event proportion at 100%, even if the site over-delivers.

For each individual event, we sum the total, uncapped delivery proportions. The delivery proportion for an event is given as:

$$DP_{s,e} = (\sum_{j=ST_e}^{FT_e} = DP_{s,j}) / (FT_e - ST_e + 1)$$

The delivery proportions can also given a grace factor, called the Reconciliation Grace Factor (RGF). Thus, if the grace factor is 0.05 i.e. 5%, then an average delivery of 95% is considered as a EP of 100%. Note that an average delivery of 94% will be considered 94%. Thus:

1) $EP_{s,e} = 1 \; if \; 1 \leq DP_{s,e} + RGF < 1 + RGF$
2) $EP_{s,e} = DP_{s,e} \; otherwise$

Thus, the Reconciliation Factor is then $1 - EDP_{s,m}$

Monthly Arming Window Payments

We are now able to calculate the payment due to a participant for a given month:

$$AWP_{s,m} = (\sum_{aw\epsilon \, M} AWP_{s,aw}) \, . \, EDP_{s,m}$$

That is, the total arming window payments due multiplied by the delivery proportion.

Dynamic Service

Similar to *Secure*, the *Dynamic* service differs in the payment of availability rather than arming payments. Similarly, utilisation payments are given when an *event* is in progress and availability payments are given for every *window* in which the site is deemed to be available.

Availability payments and utilisation payments are calculated at a different granularity, which we call the *settlement period*. The constants that we use to convert between MWh values and the individual time segments are SP_u and SP_a which correspond to the fraction of an hour for utilisation and availability. In our case, the utilisation settlement period is 1 minute, and availability settlement period is 30 minutes i.e. $SP_u = \frac{1}{60}$ and $SP_a = 0.5$.

For each site, we have three constant values:

- A contracted capacity (CC_s) , given in MW, which is generation or load reduction that a site must be available to perform during a window, and must deliver during a *Dynamic* event.
- A utilisation cost (UC_s), which is the payment per MWh delivery by the site
- An availability cost (AC_s) , which is the payment per MW per hour of availability of the site

Payments are calculated on a month-by-month basis. The two main calculations in this document determine the utilisation and availability payments due to a site for a given month.

For each month, (m), we have a list of windows and a list of events, which we will write as (W_m) and (E_m). The top-level calculations will loop through these lists, but the bulk of the work is performed for an individual window and an individual event.

Window Availability Payments

Availability payments for a given window, w, are determined as the sum for all settlement periods in that window, based on binary values for site availability that are supplied into the payment calculator of each site.

We write ST_w and FT_w for the start and finish periods of a given window, abstracting away from the length of a given period. We enforce $ST_w < FT_w$.

The raw availability payment given to a site for a window is given as follows:

$$AP_{s,w} = (\sum_{j=ST_w}^{FT_w} AC_s . SP_a . CC_s . SA_{s,j})$$

Where:

- $AP_{s,w}$ is the *Dynamic* availability payment for site (s) during window (w)
- $\sum_{j=ST_w}^{FT_w}$ sums the payment for every time period in the window, from start to finish time inclusive.
- $SA_{s,j}$ is the site availability for that settlement period, which is supplied as binary data into the system, based on the reporting and the conditions outlined elsewhere in the contract.
- AC_s and CC_s are the site constants defined above.
- SP_a is the availability settlement period

A site is paid for a given settlement period within the window if it has been determined to be available for that individual settlement period in the window. Thus, if a site is unavailable for any portion of a window, there is financial incentive to fix the problem for the remaining portion of the window.

The payment per settlement period is given as the product of the availability cost (per MWh), and the contracted capacity of the site multiplied by the fraction of an hour that the settlement period represents. To illustrate, a 1MW site, at a price of £10/MWh will be paid £5 per SP_a. A 0.5MW site at the same price will be paid £2.50 per SP_a. If that site is available throughout the entirety of a 20 period long (10 hours) window, they will be paid 20 x 2.50 = £50.

Event Utilisation payments

For a given site (s), utilisation payments are calculated per-Event (e). Similarly to availability payments, each event has a start time (ST_e) and a finish time (FT_e) such that $ST_e < FT_e$.

$$U_{s,e} = \sum_{j=ST_e}^{FT_e} CC_s . UC_s . SP_u . PP(CC_s, AD_{s,j})$$

Where:

- $U_{s,e}$ is the utilisation payment for site (s) during *Dynamic* event (e)
- $\sum_{j=ST_e}^{F_e}$ sums over the time segments in the event.

- CC_s , UC_s , and SP_u are the contracted capacity, utilisation cost and settlement period of the site, as defined above.
- The function PP , defined below, is the *Payment Proportion* and works out what fraction of the full price is due to the site for every settlement period
- $AD_{s,j}$ is the actual, metered delivery of the site *(s)* for time segment *(j)* . In the payment calculations, there is no difference between generator sites and demand reduction sites, since this value is the 'reported to grid' value.

Payment Proportion

A site is awarded full payment for greater than or equal to perfect performance, or performance within a margin of error for under-delivery, known as the *grace factor* (GF).

If the site does not deliver the contracted capacity, they may be penalised, based on the rules defined below.

We define the *Delivery Proportion* $(DP_{s,j})$ as the ratio of actual delivery to contracted capacity, This ratio is a value that represents a percentage. For example an actual delivery of 2.5MW and contacted capacity of 2MW is $\frac{2.5}{2} = 1.25 = 125\%$. An actual delivery of 1.5MW for the same capacity is $\frac{1.5}{2} = 0.75 = 75\%$. It is given as follows:

$$DP_{s,j} = Round(\frac{AD_{s,j}}{CC_s})$$

where the raw proportion is rounded to two significant figures to ensure it represents a whole percentage. This means, for example, that a delivery proportion of 0.945 gets rounded upwards to 0.95 (95%), whereas 0.950000001 gets rounded down to 0.95 (95%).

The Grace Factor determines the acceptable under-delivery for a site. Then for every % point under that level, a fixed proportion (called the penalization multiplier, *PM*) of their due payment is rescinded. Over-delivery is paid at contracted capacity.

For example, assume a *PM* of 3 and a *GF* of 5%. Then, for a time period *j*, if

- $DP_{s,j} = 100\%$ then 100% payment is given
- $DP_{s,j} = 120\%$ then 100% payment is given

- $DP_{s,j} = 96\%$ then 100% payment is given
- $DP_{s,j} = 95\%$ then 100% payment is given
- $DP_{s,j} = 94\%$ then $95\% - PM = 92\%$ payment is given
- $DP_{s,j} = 93\%$ then $95\% - 2.PM = 89\%$ payment is given
- And so on, until 0% payment is due

Thus, the Payment Proportion is a value between 0 and 1 (or 0 and 100%). The calculation is a little complex as contains two separate cases:

1) $PP_{s,j} = 1, if\ DP_{s,j} \geq (1 - GF)$

2) $PP_{s,j} = Max(0,\ 1 - GF - PM.[1 - GF - DP_{s,j}]), if\ DP_{s,j} < (1 - GF)$

The first case is where the delivery proportion is greater than 100% minus the grace factor. If this is the case, then precisely 100% payment is given. If delivery proportion is less than that, then it is subject to punitive measures. The $Max(0, x)$ part ensures that payment between 0% and 100%. For every percentage point *below* the grace factor, the penalisation multiplier is applied, which is calculated as: $PM.[1 - GF - DP_{s,j}]$. Then, that is subtracted from the grace factor limit (which is $1 - GF$). We illustrate:

Examples.

Using our examples above (with *GF* = 0.05 (5%) and *PM* = 3), then

1) $if\ DP_{s,j} \geq (1 - 0.05) \geq 0.95\ then\ PP_{s,j} = 1$

- For $120\% = 1.2$, i.e. full payment.
- Similarly for 100%.
- For 95%, we have $DP_{s,j} \geq (1 - GF)$ i.e. $0.95 \geq 0.95$ so $PP_{s,j} = 1$ again i.e. full payment.

The other case:

2) $if\ DP_{s,j} < (1 - 0.05) < 0.95\ then...$

$$PP_{s,j} = Max(0,\ 1 - 0.05 - 3.[1 - 0.05 - DP_{s,j}]) = Max(0, 0.95 - 3.[0.95 - DP_{s,j}])$$

- For $94\% = 0.94$, it is $Max(0, 0.95 - 3.[0.95 - 0.94] = Max(0, 0.95 - 3.0.01) = Max(0, 0.92) = 92\%$

- For $70\% = 0.7$, it is $Max(0{,}0.95 - 3.[0.95 - 0.7] = Max(0{,}0.95 - 3.0.25) = Max(0{,}0.2) = 20\%$
- For $64\% = 0.64$, it is $Max(0{,}0.95 - 3.[0.95 - 0.64] = Max(0{,}0.95 - 3.0.31) = Max(0{,}0.02) = 2\%$
- For $63\% = 0.63$, it is $Max(0{,}0.95 - 3.[0.95 - 0.63] = Max(0{,}0.95 - 3.0.32) = Max(0, -0.01) = 0\%$

Monthly Reconciliation

There is also a monthly reconciliation payment taken from availability payments for sites based on their individual utilisation performance over the month.

We calculate it as follows. The Event Delivery Proportion $(EDP_{s,m})$ for a site for a given month is:

$$EDP_{s,m} = \frac{\sum_{e\,\epsilon\,Em} \quad Min(1, EP_{s,e})}{\#E_m}$$

I.e. the capped proportion of average deliveries for a participant in a given month.

- $e \,\epsilon\, E_m$ is every event in the set of events for the month m.
- $\#E_m$ is the number of events in the month
- $Min(1, EP_{s,e}\ \ )$ caps the event proportion at 100%, even if the site over-delivers. The Event Proportion $EP_{s,e}$ for a site and an event is defined below.

In order to define the Event Proportion, we first need the Delivery Proportion. For each individual event, we sum the total, uncapped delivery proportions. The delivery proportion for an event is given as:

$$DP_{s,e} = (\sum_{j=ST_e}^{FT_e} \quad = DP_{s,j})\ /(FT_e - ST_e + 1)$$

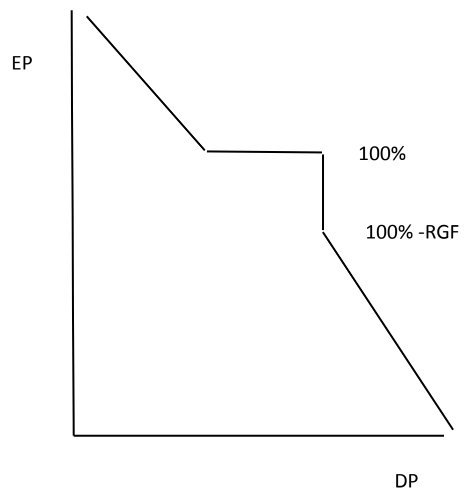
That is, we calculate the delivery proportion for each individual time segment of the event. It is important to note that this is **uncapped** so the first half of the event can under deliver at 90% and the second half can over deliver at 110% to give a total event proportion of 100%. This does not apply across events in the month, as shown in the $EDP_{s,m}$ calculation.

When calculating the event proportion, the delivery proportions can also be given a grace factor, called the Reconciliation Grace Factor *(RGF)*. Thus, if the grace factor is 0.05 i.e. 5%, then an average delivery proportion of 95% is considered as an event proportion of 100%. Note that an average delivery proportion of 94% will be considered an event proportion of 94%.

Thus, the event proportion is:

1) $EP_{s,e} = 1 \; if \; 1 \leq DP_{s,e} + RGF < 1 + RGF$
2) $EP_{s,e} = DP_{s,e} \; , otherwise$

This unusual equation is saying that if the delivery proportion is between 100% and 100% - *RGF*, then event proportion will be 100%; otherwise, it will be its exact value.



Note that the event delivery proportion is the average of a set of values between 0 and 1. It will itself be between 0 and 1. It is the average monthly delivery proportion

Thus, we Reconciliation Factor is then $1 - EDP_{s,m}$

Monthly Availability Payments

We are now able to calculate the payment due to a participant for a given month:

$$AP_{s,m} = (\sum_{w \epsilon M} AP_{s,w}) \, . \, EDP_{s,m}$$

That is, the total availability payments due multiplied by the delivery proportion.

Monthly Utilisation Payments

Similarly, we calculate the utilisation payment due for a given site in a month as the sum of the individual event utilisation payments:

$$UP_{s,m} = (\sum_{e \epsilon\, M} UP_{s,e})$$

Restore Service

The *Restore* service is expected to be offered very infrequently. For this reason, we have no availability payments and no monthly reconciliation: we only have the actual utilisation payment. There are some similarities with the utilisation payment mechanics of the previous two services described, but the *Restore* utilisation payment differs in that:

- It does not include a Grace Factor which recognises performance at a certain threshold and round this up;
- There is a linear relationship between % performance and payments from 80% up to the performance cap;
- Below 80% the penalty multiplier is only a factor of 2 instead of 3;
- It introduces a *payable over delivery* $(PO\quad)$: a specified amount above the contracted capacity through which delivery will be paid `at rate'

As before, for a given site(s), utilisation payments are calculated per-Event (e). Each event has a start time (ST_e) and a finish time (FT_e) such that $ST_e < FT_e$. We write $U_{s,e}$ for the utilisation payment

$$U_{s,e} = \sum_{j=ST_e}^{FT_e} CC_s \,.\, UC_s \,.\, SP_u \,.\, PP\quad (CC_s, AD_{s,j})$$

Where:

- $U_{e,s}$ is the utilisation payment for site (s) during event (e)
- $\sum_{j=ST_e}^{F_e}$ sums over the time segments in the event.
- CC_s , UC_s, and SP_u are the contracted capacity, utilisation cost and settlement period of the site, as defined above.
- $AD_{s,j}$ is the actual, metered delivery of the site (s) for time segment *(j).* In the payment calculations, there is no difference between generator sites and demand reduction sites, since this value is the 'reported to grid' value.
- The function PP, defined below, is the *Payment Proportion* and works out what fraction of the full price is due to the site for every settlement period for the *Restore* service.

Payment Proportion

There are three variables that are applied to customise the utilisation payment for each service:

1. A site is awarded full payment for greater than or equal to perfect performance, or performance within a margin of error for under-delivery, known as the *grace factor* (GF)
2. If the site does not deliver the contracted capacity, they may be penalised by a *penalization multiplier*, (PM), based on the rules defined below.
3. Over-delivery may or may not be paid, based on the *payable over delivery* $(PO\quad)$ which defines the % overpayment above 100% that will be given. A *PO* of 0.1 (10%), represented as a decimal between 0-1, for example will mean that a site will be paid up to 110% of their contracted capacity if they over-deliver by that amount.

We define the *Delivery Proportion* $(DP_{s,j})$ as the ratio of actual delivery to contracted capacity, This ratio is a value that represents a percentage. For example an actual delivery of 2.5MW and contacted capacity of 2MW is $\frac{2.5}{2} = 1.25 \; = \; 125\%$. An actual delivery of 1.5MW for the same capacity is $\frac{1.5}{2} = 0.75 \; = \; 75\%$. It is given as follows:

$$DP_{s,j} \; = Round(\frac{AD_{s,j}}{CC_s})$$

where the raw proportion is rounded to two significant figures to ensure it represents a whole percentage. This means, for example, that a delivery proportion of 0.945 gets rounded upwards to 0.95 (95%), whereas 0.950000001 gets rounded down to 0.95 (95%).

The Delivery Target threshold *(DTT)* determines the acceptable under-delivery for a site. Then for every % point under that level, a fixed proportion (called the penalization multiplier, *PM*) of their due payment is rescinded. Over-delivery is paid up until the payable over delivery *(PO)* mark is hit.

For example, assume a *PM* of 2, a *DTT* of 20%, and a *PO* of 10%. Then, for a time period *j* , if

- $DP_{s,j} \; = \; 100\%$ then 100% payment is given
- $DP_{s,j} \; = \; 120\%$ then 110% payment is given

- $DP_{s,j} = 96\%$ then 96% payment is given
- $DP_{s,j} = 80\%$ then 80% payment is given
- $DP_{s,j} = 79\%$ then $80\% - PM = 78\%$ payment is given
- $DP_{s,j} = 76\%$ then $80\% - 4.PM = 72\%$ payment is given
- And so on, until 0%payment is due

Thus, the Payment Proportion is a value between 0 and *1+PO* (or 0 and 100%+PO%). The calculation is subtly different from those above, containing three cases:

1) $if\ DP_{s,j} \geq (1 - DTT)\ and\ DP_{s,j} \leq 1 + PO, PP = DP_{s,j}$

2) $if\ DP_{s,j} < (1 - DTT), PP = Max\left(0,\ 1 - DTT - PM.\left[1 - DTT - DP_{s,j}\right]\right)$

3) $if\ PP_{s,j} = 1 + PO, DP_{s,j} > 1 + PO$

The first case is where the delivery proportion is greater than 100% minus the grace factor, but less than the paid over delivery. If this is the case, then the precise delivery proportion is paid. If it is more than the paid over delivery, then payment is capped at that over delivery value. If delivery proportion is less than the Delivery Target Threshold, then it is subject to punitive measures. For every percentage point *below* the Delivery Target Threshold, the penalisation multiplier is applied, which is calculated as: $PM.[1 - DTT - DP_{s,j}]$. Then, that is subtracted from the Delivery Target Threshold limit (which is $1 - DTT$).