The webinar will start shortly.
To maximise participation and minimise disruption, please make sure you are on mute and your camera is turned off.
Please note that the webinar will be recorded.

Consultation webinar: DM & DR technical deep dive

30 November 2021

nationalgridESO

Agenda

1. Performance monitoring
2. State of Energy
3. Testing

Q&A

- Q&A at the end of each section
- Presenter will let you know when it is time for questions
- Raise your hand to ask a question
- Come off mute to ask your question


Performance monitoring

Performance monitoring – DM and DR

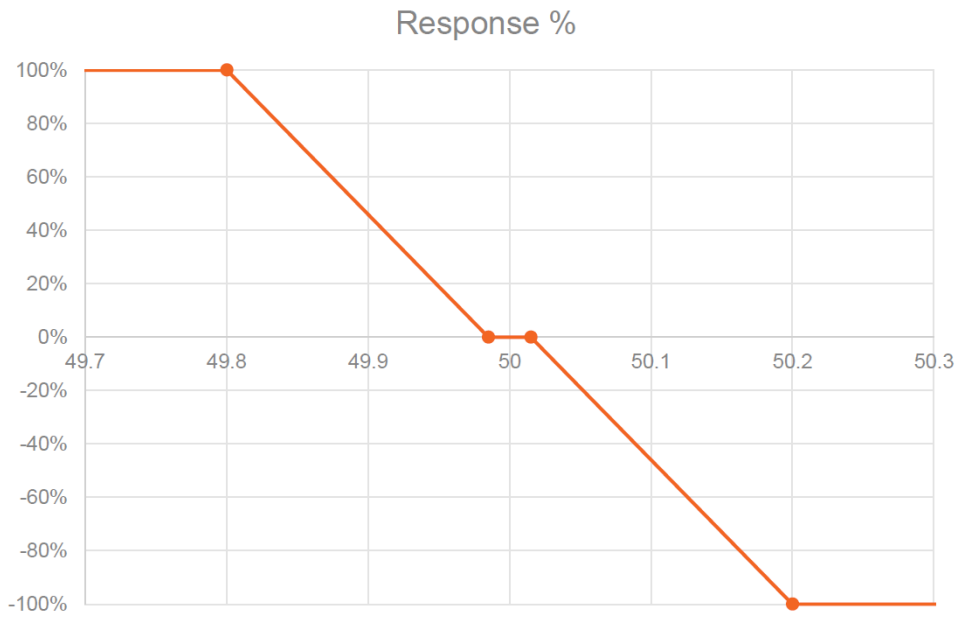
- Service Terms parameters for Performance Monitoring

Parameter	DM (Similar to DC)	DR
Data Frequency	20Hz	2Hz*
Max initiation time (T_{iMAX})	0.5s	2s
Max time to full delivery (T_{dMAX})	1s	10s
Ramp time (tr_{max})	0.5s	8s

Response curve

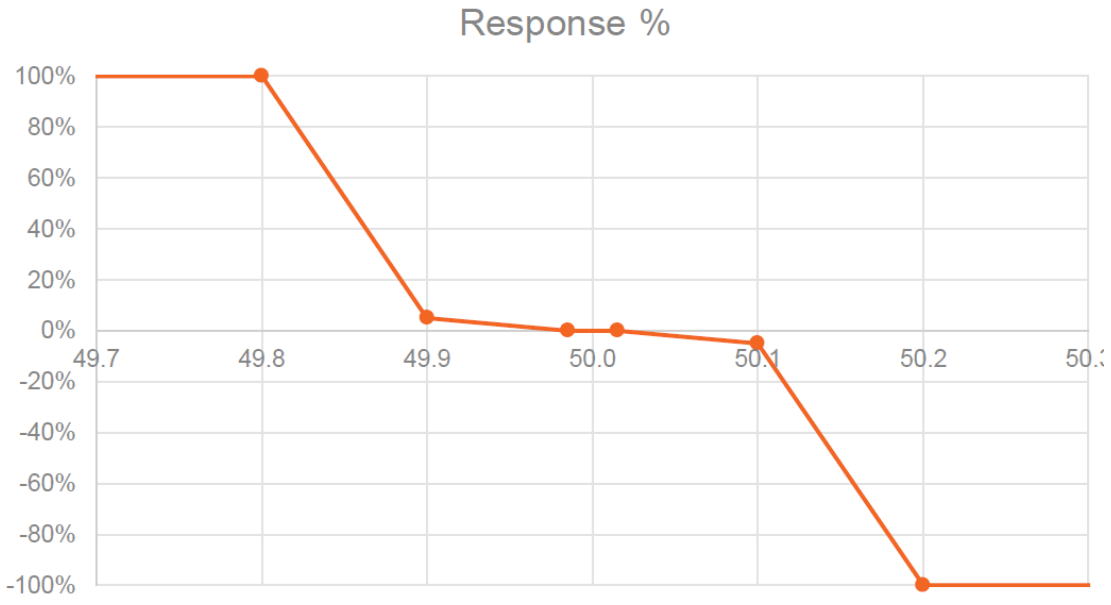
Dynamic Regulation

Saturation	$f_{S\pm} = f_0 \pm 0.2$ Hz	$R_{S\pm} = \mp 100\%$
Delivery/deadband	$f_{D\pm} = f_0 \pm 0.015$ Hz	$R_{D\pm} = 0\%$



Dynamic Moderation

Saturation	$f_{S\pm} = f_0 \pm 0.2$ Hz	$R_{S\pm} = \mp 100\%$
Activation	$f_{A\pm} = f_0 \pm 0.1$ Hz	$R_{A\pm} = \mp 5\%$
Delivery/deadband	$f_{D\pm} = f_0 \pm 0.015$ Hz	$R_{D\pm} = 0\%$



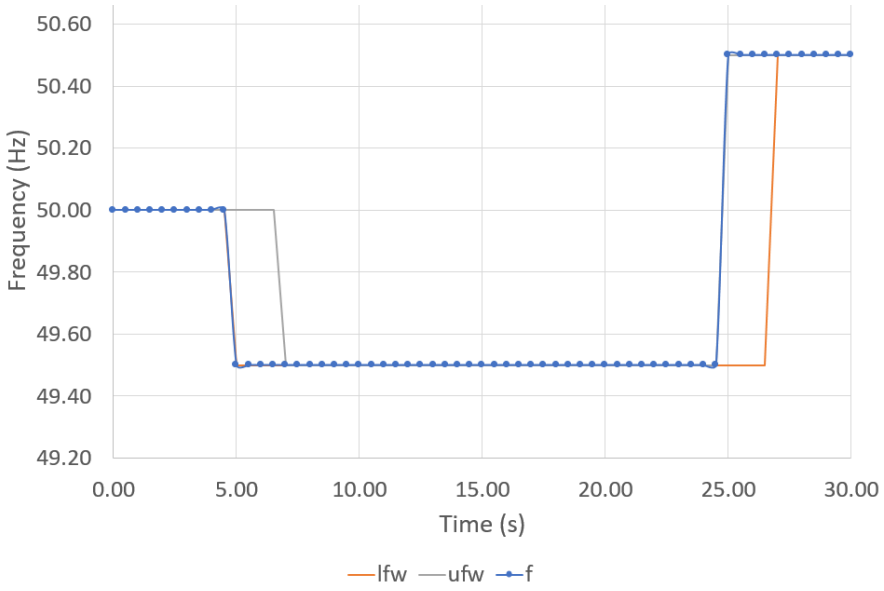
Frequency Bounds

Dynamic Regulation

$$F^{upper}(t) = \max_{0 \le t_{lag} \le \mathrm{T_{iMAX}}} f(t - t_{lag})$$

$$F^{lower}(t) = \min_{0 \le t_{lag} \le \mathrm{T_{iMAX}}} f(t - t_{lag})$$

Lag upper bound (maximum initiation time): $\mathrm{T_{iMAX}} = 2\ s$



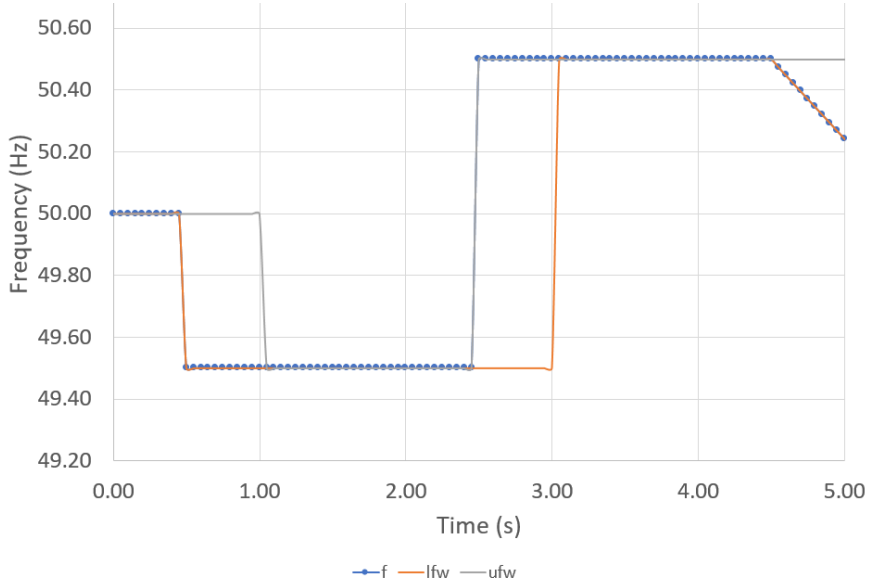
Dynamic Moderation

$$F^{upper}(t) = \max_{0 \le t_{lag} \le \mathrm{T_{iMAX}} + tol_{iMAX}} f(t - t_{lag})$$

$$F^{lower}(t) = \min_{0 \le t_{lag} \le \mathrm{T_{iMAX}} + tol_{iMAX}} f(t - t_{lag})$$

Lag upper bound (maximum initiation time): $\mathrm{T_{iMAX}} = 0.50\ s$

Lag upper bound tolerance: $tol_{iMAX} = 0.05\ s$



Performance Bounds

Performance bounds for LF only

$$UB_{LF}(t) = RLD\left(R_{LF}\left(F^{lower}(t)\right), rr_{min}\right) \times P$$

$$LB_{LF}(t) = RLU\left(R_{LF}\left(F^{upper}(t)\right), rr_{min}\right) \times P$$

Performance bounds for HF only

$$UB_{HF}(t) = RLD\left(R_{HF}\left(F^{lower}(t)\right), rr_{min}\right) \times Q$$

$$LB_{HF}(t) = RLU\left(R_{HF}\left(F^{upper}(t)\right), rr_{min}\right) \times Q$$

Performance bounds for LF and HF

$$UB(t) = ub(t) \times \begin{cases} P & ub(t) \geq 0 \\ Q & ub(t) < 0 \end{cases}$$

$$LB(t) = lb(t) \times \begin{cases} P & lb(t) \geq 0 \\ Q & \text{lb}(t) < 0 \end{cases}$$

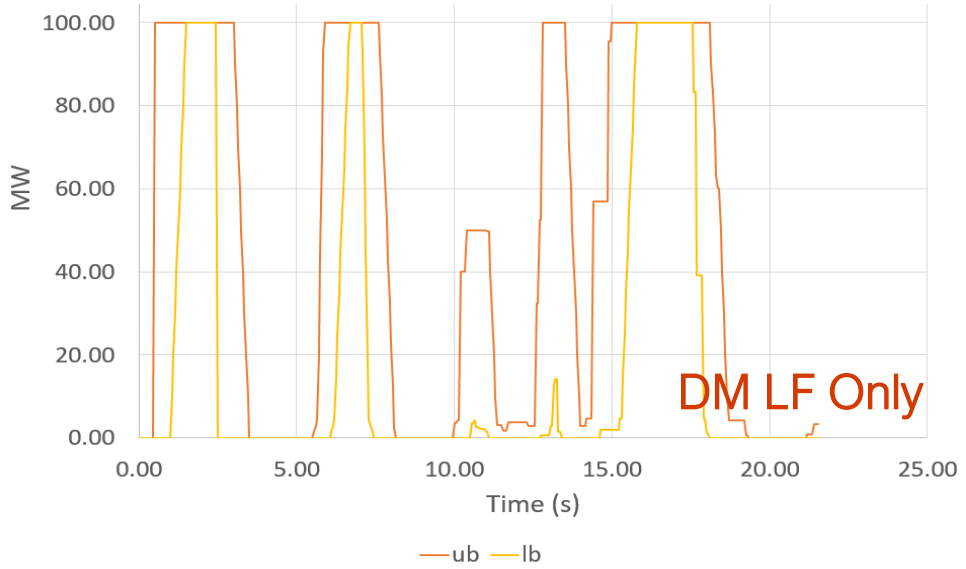
Where:

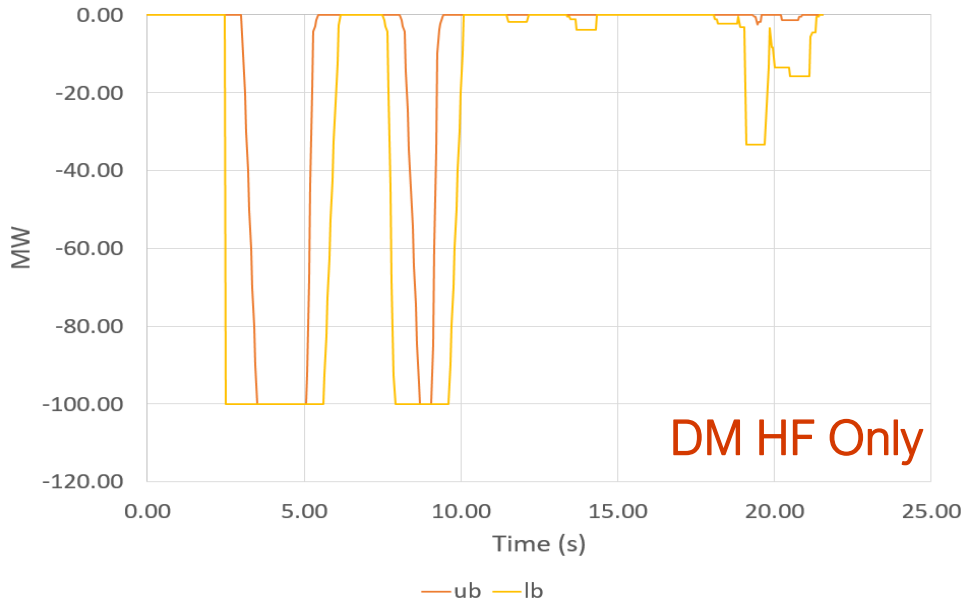
$$ub(t) = RLD\left(R_{sym}\left(F^{lower}(t)\right), rr_{min}\right)$$

$$lb(t) = RLU\left(R_{sym}\left(F^{upper}(t)\right), rr_{min}\right)$$

Parameter	DM	DR
Ramp rate (MW/s)	$2 * CQ$	$0.125 * CQ$

CQ = Contracted Quantity





Performance Bounds DM

For the first **0.55 seconds** after a response unit begins delivery, after a period of missing data, or after switching from unavailable to available the upper and lower performance bounds will be set to P and -Q respectively.

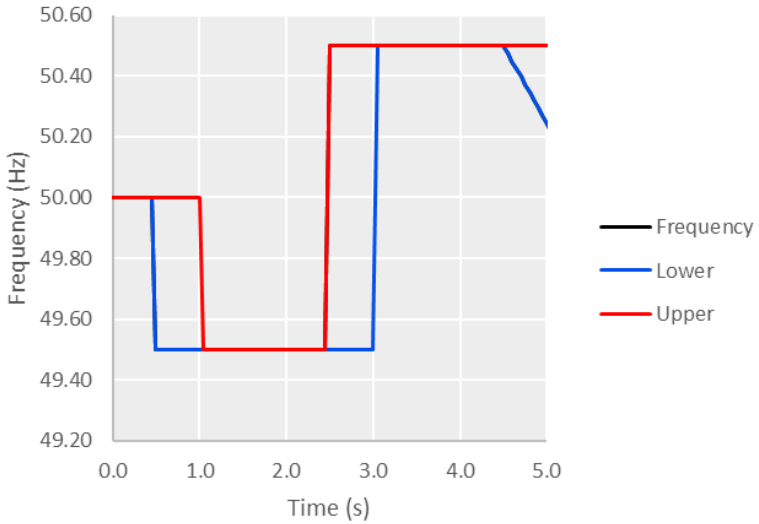
2 seconds for DR

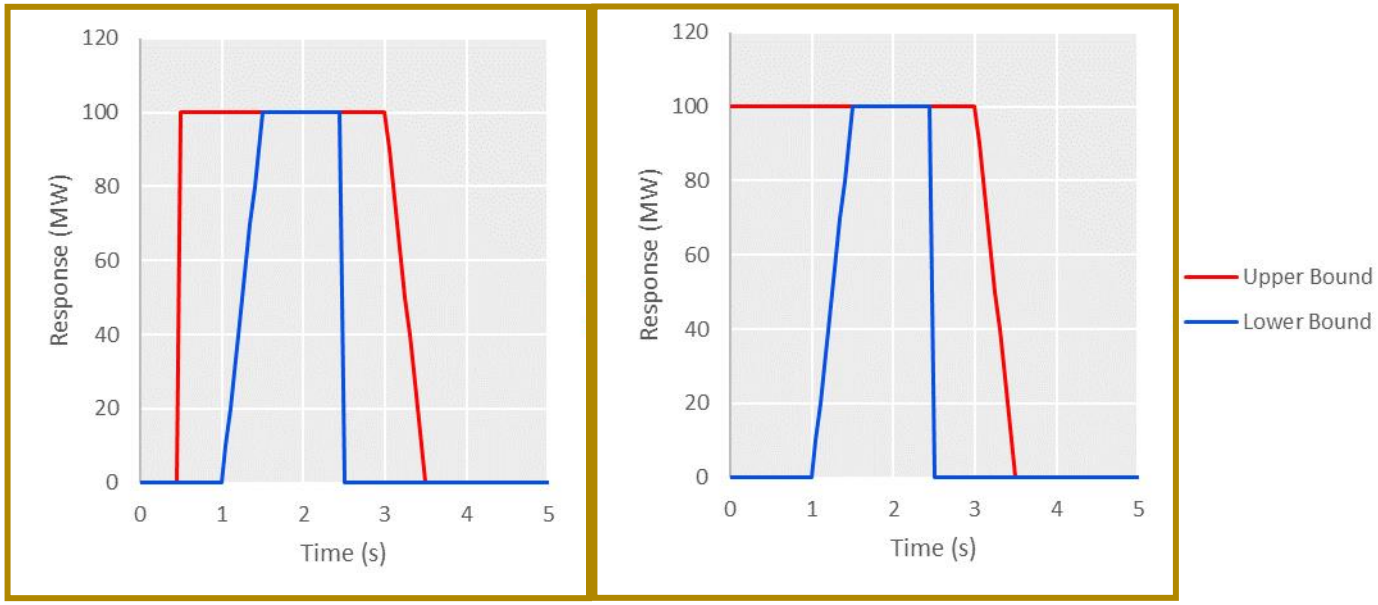
To allow time to change between contracts (a change in P or Q): the performance bounds will be calculated for **1 second** after the change using whichever of the contracts gives the lower bound, and the higher upper bound.

10 seconds for DR

Performance Bounds DM

Example for DM LF 100MW:





No window

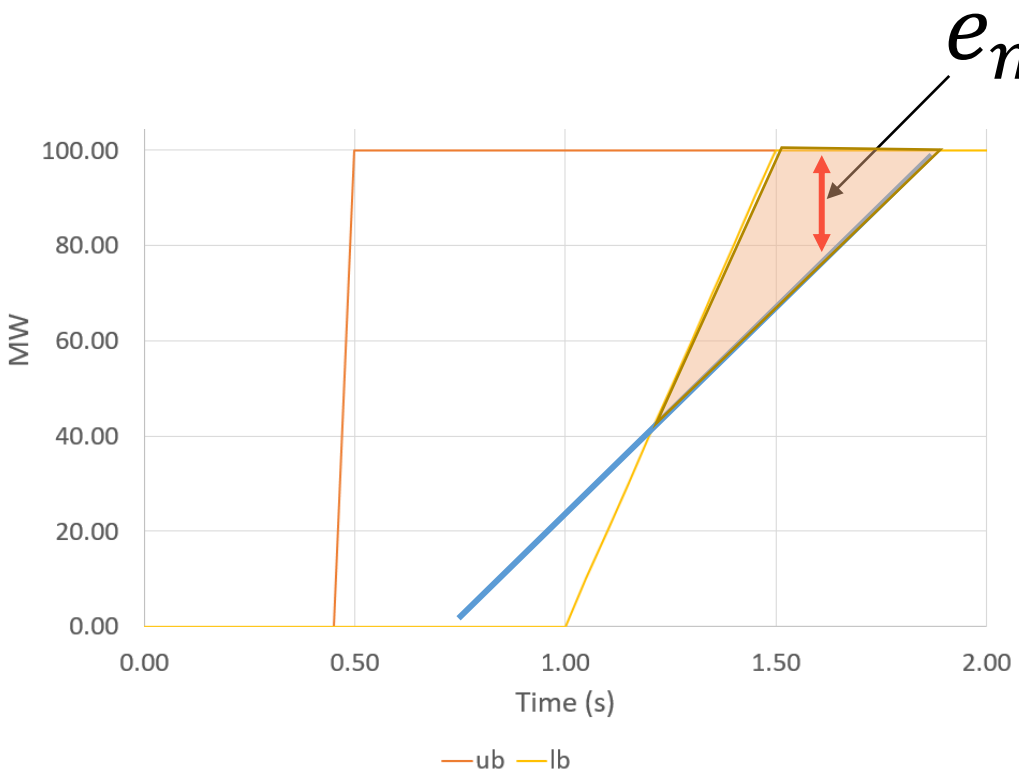
0.55s window

Error Calculation

$$e_m = \begin{cases} LB - R & R < LB \\ 0 & LB \leq R \leq UB \\ R - UB & R > UB \end{cases}$$

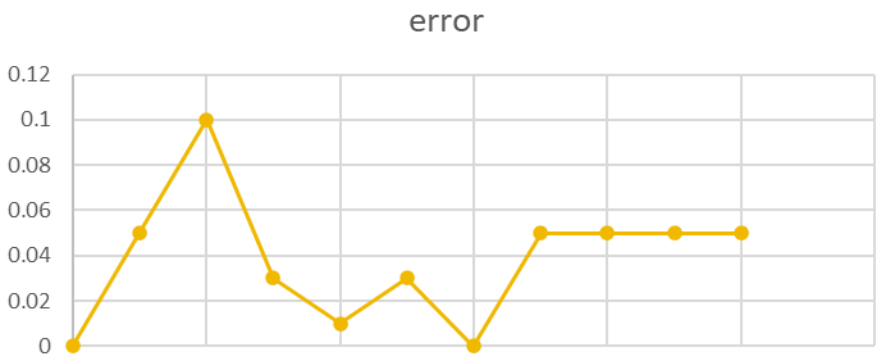
$$es_m = \frac{e_m}{P} \qquad es_m = \frac{e_m}{Q}$$

$$es_m = \begin{cases} \frac{e_m}{Q} & F^{lower}{}_m > 50 \\ \frac{e_m}{P} & F^{upper}{}_m < 50 \\ \frac{e_m}{\max(P,Q)} & \text{otherwise} \end{cases}$$

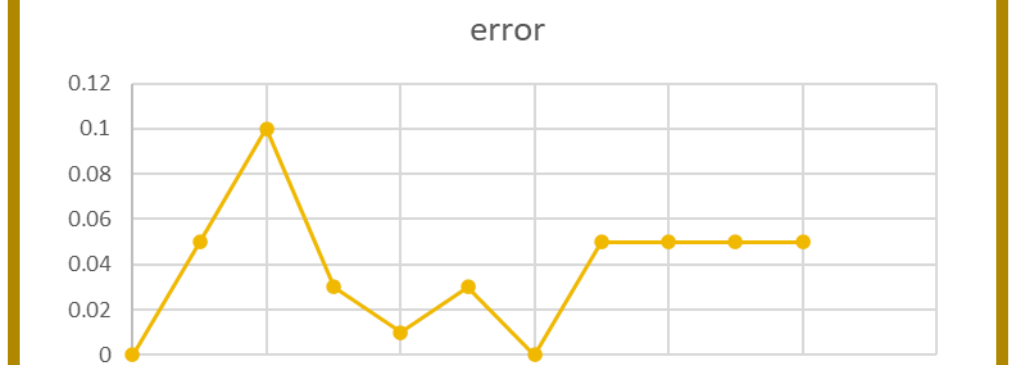


Error Calculation

Dynamic Regulation



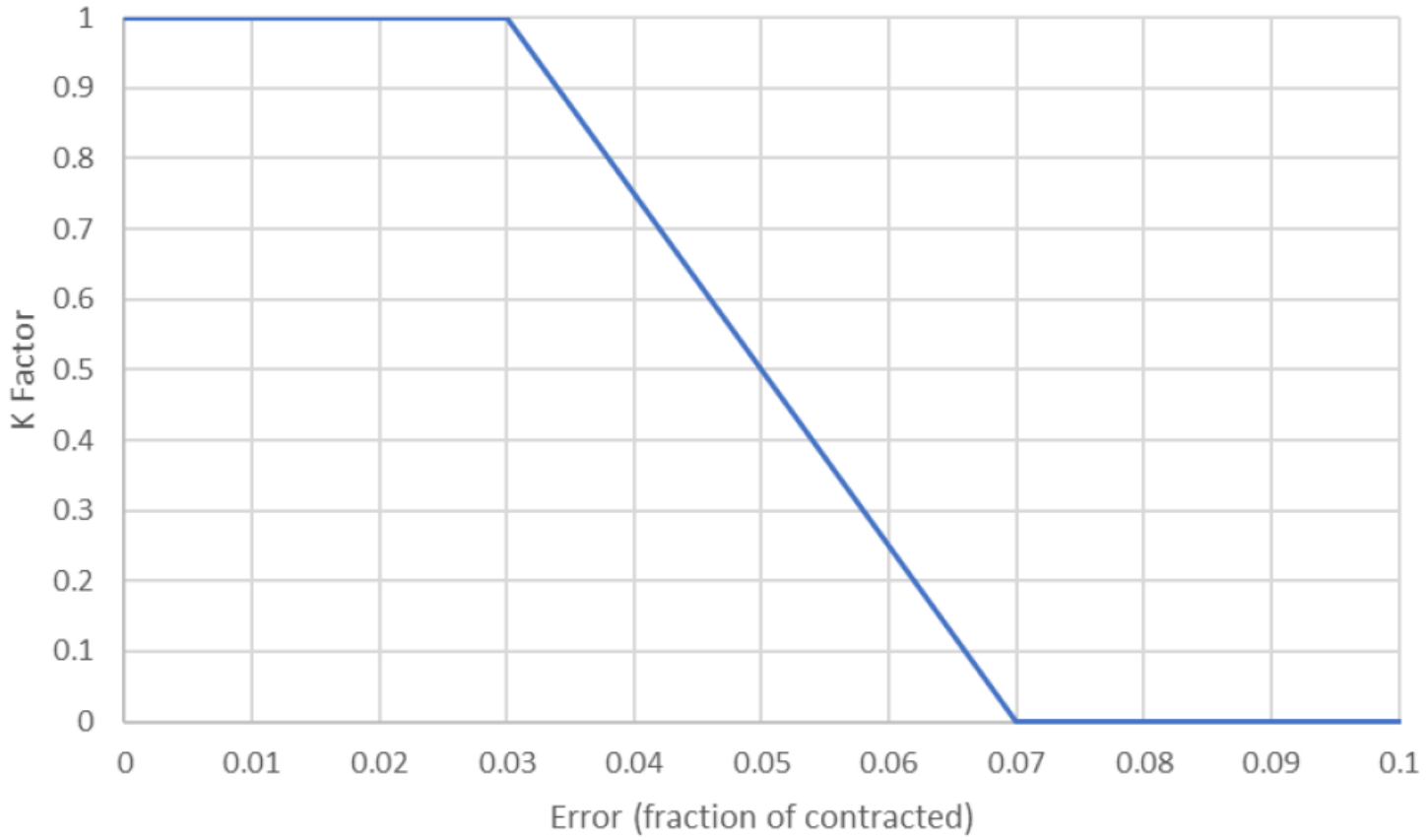
Dynamic Moderation



K Factor

$$k_j = \begin{cases} 1 & E < A \\ 1 - (E - A)/(B - A) & A \leq E \leq B \\ 0 & E > B \end{cases}$$

$$K_e = \min_j k_j$$



Disarming/Re-Arming

For the purpose of **Performance Monitoring**, and unless and until otherwise specified by NGESO for the duration of a Disarming Instruction (and for the avoidance of doubt until any Re-Arming Instruction) the Response Unit shall be deemed to have delivered the service with a deemed Contracted Quantity of zero (0) MW.


State of Energy

State of Energy

The solution to SoE management for DM and DR is to require energy limited units to:

1. Begin the EFA Block with a level of stored energy (i.e. **Response Energy Volume**) adequate for its contracted response quantity (i.e. **Contracted Quantity**).

2. Review the level of stored energy at the start of each settlement period during that EFA Block, looking at the net energy delivery in the previous settlement period.

3. Aim to return the stored energy level to an appropriate level (i.e. **Energy Recovery**) by the submission (and following) of **Operational Baselines**. This means charging or discharging by following a baseline.

State of Energy - Glossary

- **Contracted Quantity**

  The amount of Response (MW) which a Service Provider has agreed to provide.

- **Delivery Duration**

  30 minutes for DM; 60 minutes for DR

- **Response Energy Volume**

  The amount of stored energy (or capability to store energy) that a Response Unit should be capable of delivering before becoming unavailable due to exhaustion.

Response Energy Volume [MWh] = **Contracted Quantity** [MW] x **Delivery Duration** [0.5 h] for DM
= **Contracted Quantity** [MW] x **Delivery Duration** [1 h] for DR

- **Energy Recovery**

  The minimum volume of stored energy (or capability to store energy) capable of being recovered by way of State of Energy management in a single Settlement Period.

Energy Recovery [MWh] = 20% x **Response Energy Volume** [MWh]

State of Energy – Example

Contracted Quantity equals 50MW of low response for DM and DR respectively

Parameters	DM	DR
Contract Quantity	50MW	50MW
Delivery Duration	0.5h	1h
Response Energy Volume	25MWh	50MWh
Energy Recovery	5MWh	10MWh

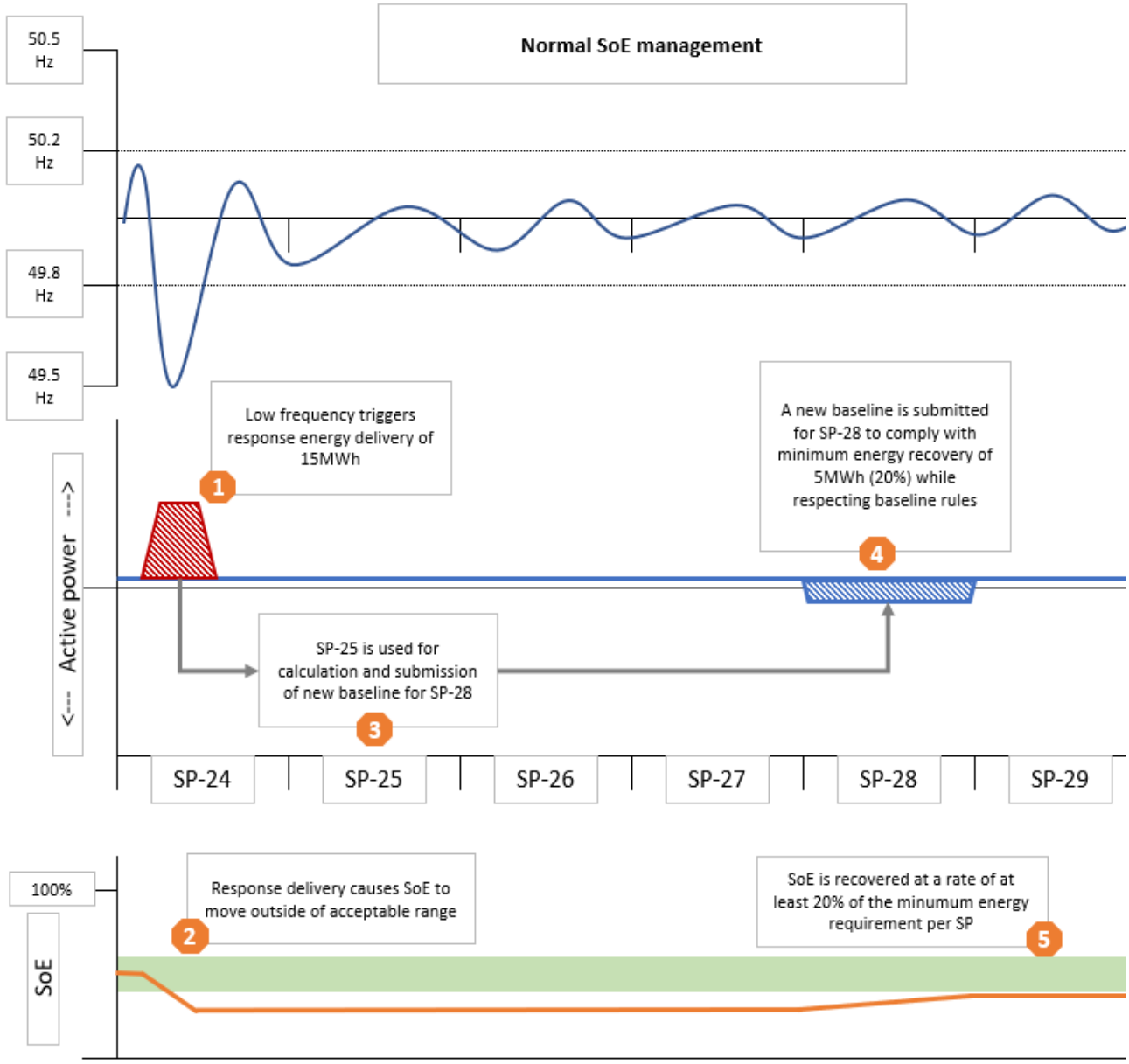
State of Energy

Parameters	DM	DR
Contract Quantity	50MW	50MW
Delivery Duration	0.5h	1h
Response Energy Volume	25MWh	50MWh
Energy Recovery	5MWh	10MWh

- Begin the contracted period with **25MWh** of energy in the relevant direction.
- In **SP-24** the unit delivered **15MWh** of energy as it responded to frequency.
- At the start of **SP-25** the stored energy is now **10MWh**, hence, submit a baseline to replenish at least **5MWh** at **SP-28**.
- …

Note:

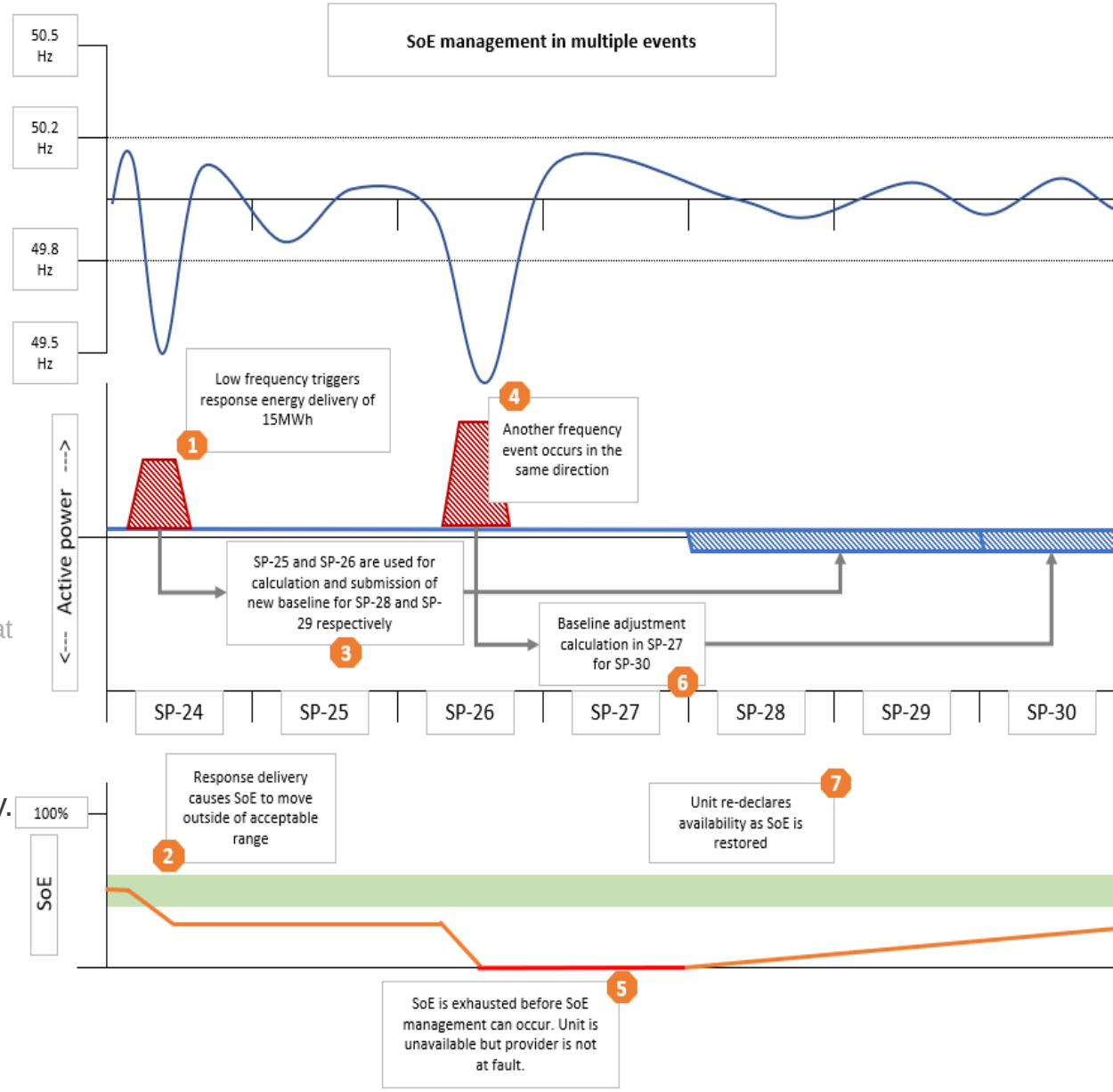
- There is a 1 hour gate before baselines can apply, i.e. **SP-25** and **28**
- Maximum ramp rate is **5%** of **Contracted Quantity**, i.e. **2.5 MW/min**



State of Energy

Parameters	DM	DR
Contract Quantity	50MW	50MW
Delivery Duration	0.5h	1h
Response Energy Volume	25MWh	50MWh
Energy Recovery	5MWh	10MWh

- Begin the contracted period with **25MWh** of energy in the relevant direction
- In **SP-24** the unit delivered **15MWh** of energy as it responded to frequency.
- At the start of **SP-25** the stored energy is now **10MWh**, hence, submit a baseline to replenish at least **5MWh** at **SP-28**.
- At the start of **SP-26** the stored energy is still **10MWh**, hence, submit a baseline to replenish at least **5MWh** at **SP-29**.
- During **SP-26** there is another event which fully depletes the stored energy.
- The unit is now **unavailable**. There is **no penalty** applied on performance monitoring.
- The unit should **re-declare** as **available** when SoE is restored to the **Response Energy Volume**, in this case 25MWh by:
  - At **SP-27** submit a baseline to replenish at least **5MWh** at **SP-30**.
  - At **SP-28** submit a baseline to replenish at least **5MWh** at **SP-31**.
  - Re-declare as **available** no later than **SP-32** in this case.



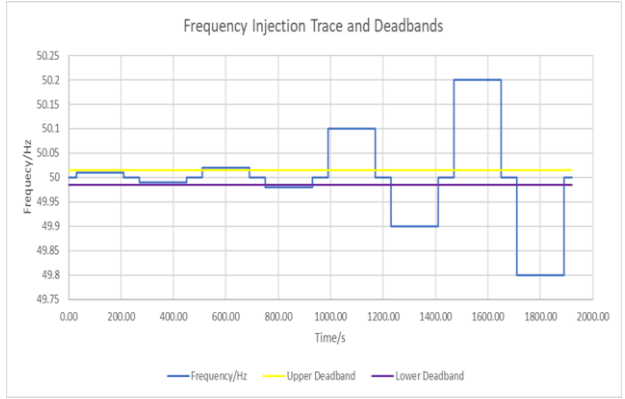

Testing

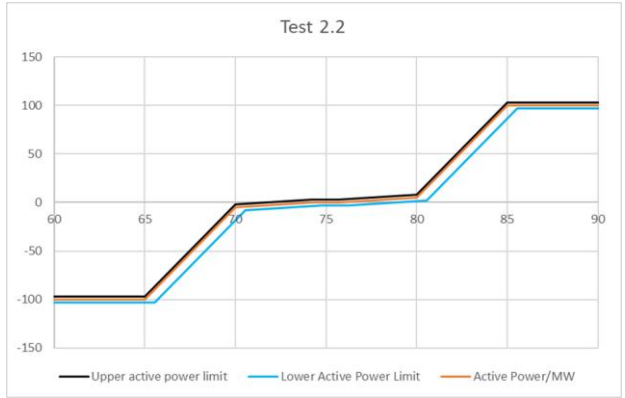
Testing

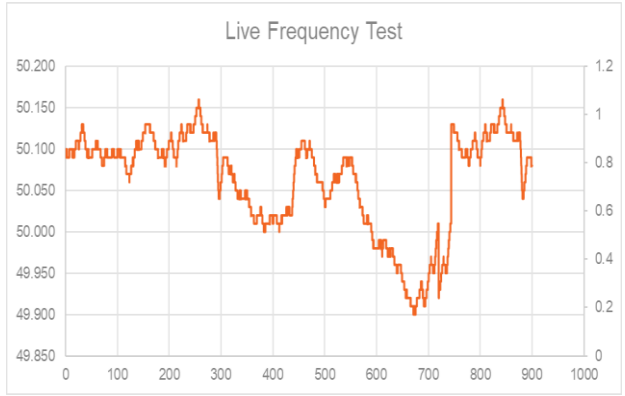
- Approach will have the look and feel of existing DC and FFR testing documentation
- DM testing is based around the current DC testing as it has a knee joint delivery
- DR testing is based on existing FFR testing as it has proportional delivery
- Testing Analysis tool for each service will be released shortly

Testing DM - Key points

- The minimum sample rate for all tests is 20Hz
- Testing is broken down into 4 tests:
  - **Test 1** - Step tests – number of tests reduced from DC to reflect full delivery at +/- 0.2
  - **Test 2** - Frequency sweep test - tests low to high and vice versa whilst staying with in tolerance bands
  - **Test 3** - Duration test - sustain full response over a 30 minute period
  - **Test 4** - Live system test - 30 minute duration plus evidence that protection settings are in line with the grid code







Testing DR - Key points

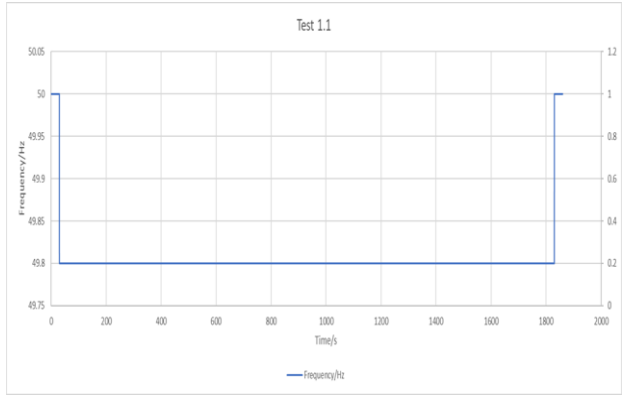
- The minimum sample rate for all tests are 10Hz for test one and a minimum 2Hz for all the other tests

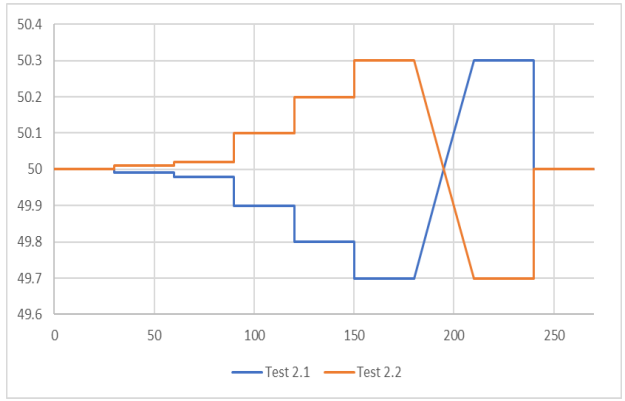
- Testing is broken down into 3 tests:

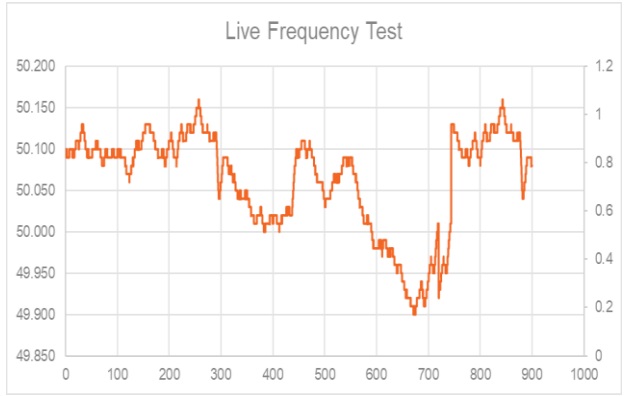
  - **Test 1** - Duration test – sustain full response over a 60 minute period – Measured at 10Hz

  - **Test 2** - Response tests – demonstrates no response inside the dead band +/- 0.015, response just outside the dead band, proportional response at differing frequency levels and response across the entire performance envelope, all whilst staying within tolerance bands

  - **Test 3** - Live system test - 60 minute duration plus evidence that protection settings are in line with the Grid Code







Consultation support

- EBR Art. 18 Consultation close – 15 December
- Service Terms video published on DM and DR webpages
- Content from webinars published on DM and DR webpages

If you have further questions, feedback or would like to request a 1-2-1, please contact: box.futureofbalancingservices@nationalgrideso.com

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