Single Electricity Market

(SEM)

SEM-24-044

TSOs' proposed definitions of Curtailment, Constraint and Energy Balancing for Non-Synchronous Renewable Generation Units

Revision to Annex 13-011

Consultation Paper

14 June 2024

EXECUTIVE SUMMARY

This consultation paper outlines Eirgrid and SONI's (TSOs') proposal for changes to SEM-13-011 (i.e. SEM 13-010 (ii), the annex to SEM-13-10, definition of Curtailment, Constraint Energy Balancing for Non-Synchronous Renewable Units).

The updates to SEM-13-011 aim to address the SEM Committee (SEM-21-027) request that the TSOs submit a revised ruleset to SEM-13-011 to reflect the changes which have occurred in the market to date, and in particular, changes to integrate non-priority dispatch renewables into existing processes. As outlined in SEM-21-027, the terminology used within the TSOs' ruleset for distinguishing between curtailment, constraint and energy balancing may require some updates for 'new renewable units' and existing priority dispatch units based on the market rules.

The RAs have engaged with the TSOs on this proposal and there has been a period of questions and answers where some changes were made. The RAs now invite industry comments on the TSOs' proposal.

In SEM 21-027, the pathway is set out as; "should the rule set published with SEM 13-011 need to be changed…it will be subject to a public consultation and approval process by the SEM Committee". Hence, any required updates to the TSOs' ruleset should be submitted by the TSOs to the SEM Committee for approval.

Interested stakeholder's views on the definitions and steps described by the TSOs, are invited until 26 July 2024, and should be submitted to schhetri@cru.ie and Bronagh.mckeown@uregni.gov.uk.

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1. Introduction

In 2018 and 2019 the EU adopted the Clean Energy for all Europeans Package (CEP). The CEP consists of eight legislative acts with the aim to facilitate a transition in the EU towards cleaner energy. One of the legislative files, the Regulation on the internal market for electricity (EU) 2019/943 (the 'Regulation') seeks to update requirements around the functioning of the EU wholesale electricity markets.

An Information Paper entitled "Roadmap to Clean Energy Package Implementation" (SEM-19-073) was published in December 2019 which identified six areas the Regulatory Authorities (RAs) needed to progress in 2020. The six areas included

Balance Responsibility and Aggregation (Articles 5, 6, and 7), Priority Dispatch (Article 12), Redispatch (Article 13), Market Parameters (Articles 7, 8, 10, 11, 23, and 27), Capacity Remuneration Mechanism (Articles 20, 22, 26, and 27), Regional Coordination Centres (Article 35 and 36).

Throughout the past few years, the RAs have conducted further reviews into each of these areas and published a number of Information Papers, Consultation Papers, and Decision Papers to progress the implementation of the requirements outlined in each of these Articles. This Consultation paper is related to the work which is carried out by the TSOs as part of the Scheduling and Dispatch Programme which also includes the need to update the definitions.

1.1 Background

1.1.1. Scheduling and Dispatch Programme (SDP)

EirGrid and SONI have launched the Scheduling and Dispatch Programme (SDP) which is a programme of works developed by the Transmission System Operators. It proposes six initiatives aiming to enhance the Scheduling and Dispatch approach for intermittent renewable generation and energy storage and to introduce approaches for non-priority dispatch renewables, synchronous condensers, fast frequency response and reserve service providers.

The TSOs' Scheduling and Dispatch Programme comprises six initiatives as follows:

- SDP001 – Operation of non-priority dispatch renewables
- SDP002 – Energy Storage Power Station (ESPS) Integration
- SDP003 – Fast Frequency Response (FFR)
- SDP004 – Wind/Solar Dispatchability Improvements
- SDP005 – Reserve Services Scheduling and Dispatch
- SDP006 – Synchronous Condenser Scheduling and Dispatch

The programme includes five phases of development/implementation, and the RAs note the positive engagement that is underway between TSOs and market participants on these changes.

1.1.2. Regulatory Pathway for SEM 13-011 changes

In SEM-21-027, the SEM Committee noted that the terminology used within the TSOs' ruleset for distinguishing between curtailment and constraints set out in SEM-13-011 may require some updates to reflect the new market rules. The existing definitions were based on the presumption that all units have priority dispatch and used terminology which was no longer relevant, such as a price taking generation unit. The existing SEM-13-011 rules do not distinguish between energy balancing and dispatch or redispatch measures such as constraints and curtailment. It was on this basis that the SEM Committee proposed, in SEM-21-027, that this annex should be revised and requested the TSOs to submit a revised ruleset to SEM-13-011, to reflect these changes.

The TSOs, via letter of 4 December 2023, to the RAs, noted that without an updated ruleset, there is no published description of energy balancing actions on variable renewable units or how they should feature in the application and removal logic for constraint and curtailment. The TSOs expressed their wish to change the logic around allocation of constraint and curtailment across an affected group where constraint and curtailment would still be apportioned on a pro-rata basis, but the reference point from which this applied would change. The TSOs believe that this will ensure more equitable outcomes which can better reflect the changing unit availabilities brought about by changing weather conditions. These updates, according to the TSOs, will be

necessary for SDP001 and SDP004 of the SDP and can allow them to be included in design work for the SDP.

1.1.3 Definition of Curtailment and Constraint according to SEM 13-010

Following a series of consultations, decision paper SEM-13-010: Treatment of Curtailment in Tie-Break Situations noted the importance of a ruleset to differentiate between Constraint and Curtailment of wind generation units to allow each to be applied and compensated differently. That ruleset was published as an annex to SEM-13-010 named SEM-13-011: Definition of Curtailment and Constraint. It was subsequently decided that solar generation units would be treated in the same way as wind generation units.

The TSOs defined curtailment and constraint in 2013 in SEM-13-010 (Version 1.0 of February 2013) as follows:

"If the Control Centre assumed it had control over every price taking generation unit in tie break on the island of Ireland and the security issue presented could only be resolved by reducing the output of one or a small group of price taking generation units in tie break, then that reduction is deemed a ***constraint*** *and logged as such.*

If the Control Centre assumed it had control over every price taking generation unit in tie break on the island of Ireland and the security issue presented could be resolved by reducing the output of any or all of the price taking generation units in tie break, then that reduction is deemed a ***curtailment*** *and logged as such".*

In the case of control decisions which need to be made at a time for curtailment and constraint, the constraint decisions should be dealt with first and any remaining generation unit which needs to have their output reduced will be curtailed. Once a Curtailment instruction has been issued it is possible that this could mask the need for a subsequent Constraint instruction (and vice versa).

Generally, Curtailment and Constraint instructions are issued as Active Power Control setpoints – i.e. the unit in a tie break should reduce/increase its output to the Active Power Control setpoint and the unit's Active Power output should not exceed this level.

To comply with the Clean Energy Package Regulation (EU) 2019/943 which requires TSOs to be able to operate renewable generation units without priority dispatch (Article

12), updates are required to SEM-13-011 to add Energy Balancing actions to the ruleset. Subsequent changes will be required to these definitions and the priority dispatch hierarchy once TSO systems allow the differentiation of priority dispatch and non-priority dispatch units for constraints, which is referred to by the TSOs as the enduring dispatch arrangements.

2. Proposed Definition by the TSOs

2.1 Overview

The TSOs via their submission in March 2024 have proposed the definition of Energy Balancing, Curtailment and Constraint for Non-Synchronous Renewable Generation Units. The approach set out refers to the interim arrangements foreseen in SEM-21-027. As part of the currently named Strategic Markets Programme, the TSOs will be developing the enduring arrangements, whereby non-priority dispatch units will be redispatched prior to priority dispatch units with regard to constraints. Curtailment will continue to be pro-rata under the enduring approach.

The TSOs in the new document have added a definition of **Energy Balancing** which refers to the dispatch of controllable, non-synchronous renewable generation units without priority dispatch, to meet the energy requirements of the system in real time. According to the new document, **Constraint** of non-synchronous renewable generation refers to dispatch down due to localised network reasons, where only a subset of such generators can contribute to alleviating the problem.

Curtailment refers to the dispatch down of non-synchronous renewable generation for system- wide reasons, where the dispatch down of all such generators would alleviate the problem. There are different types of system security limits that necessitate Curtailment, for example, the System Non-Synchronous Penetration (SNSP) limit.

In a situation where the sum of total generation and net interconnector flows exceed the demand to be served, and all units without priority dispatch (both dispatchable and controllable) have been dispatched down to the lowest level possible, while maintaining system security, then units with priority dispatch are dispatched down

according to the priority dispatch hierarchy. This is also implemented as a Curtailment action for non-synchronous renewable generation units with priority dispatch.

In the case of constraints and curtailment, the TSOs have broadly maintained the underlying logic that applied in SEM-13-011 but have updated the descriptions to reflect the market changes.

2.2 Principles for Non-Market Based Application, Relaxation, Rebalancing and Removal of Constraint and Curtailment

According to the TSOs, for the **Application** of Curtailment and Constraint across a group, setpoints are calculated for each unit within the group, on a pro-rata basis, with reference to that unit's nominal output. Frequency Regulation is defined as the automatic adjustment of Active Power Output, by a Generation Unit, in response to continuous minor fluctuations of Frequency on the Power System. Frequency regulation can cause a non-synchronous renewable generation unit's Active Power Output to vary slightly from its setpoint or Available Active Power.

If the unit is not regulating for Frequency, nominal output is the unit's Actual Active Power Output. When the unit is regulating for frequency, nominal output is equal to the minimum of Available Active Power and any active setpoints.

Relaxation is the lifting of Curtailment or Constraint across a group. Setpoints for relaxation of Curtailment or Constraint are calculated on a pro-rata basis with reference to the headroom or MW difference between a unit's nominal output and its Maximum Allowable Output for relaxation (outlined below):

- For Curtailment, the maximum allowable output for relaxation is the minimum of (Available Active Power, Energy Balancing Setpoint, Constraint Setpoint), to the extent that each of these is active.
- For Constraint, the maximum allowable output for relaxation is the minimum of (Available Active Power, Energy Balancing Setpoint) *

**Note: Curtailment cannot be relaxed above a Constraint Setpoint, but a Constraint can be relaxed above a Curtailment Setpoint. Any lower Curtailment Setpoint will be lifted in line with the new Constraint Setpoint.*

For **Rebalancing** of Curtailment or Constraint within a group, setpoints are calculated on a pro-rata basis with reference to each unit's Maximum Allowable Output for Rebalancing (outlined below):

- For Curtailment:
    - The maximum allowable output for rebalancing is the minimum of (Available Active Power, Energy Balancing Setpoint, Constraint Setpoint), to the extent that each of these is active.
    - Only units where the current Curtailment Setpoint is below any active Constraint Setpoint may be included in rebalancing of Curtailment.
- For Constraint
    - The maximum allowable output for rebalancing is the minimum of (Available Active Power, Energy Balancing Setpoint, Curtailment Setpoint), to the extent that each of these is active.
    - Only units where the current Constraint Setpoint is below any active Curtailment Setpoint may be included in rebalancing of Constraint.

Rebalancing is initiated at the discretion of the grid controller to maintain system security. Rebalancing was raised as a concern by the market participants due to the perceived unfairness caused, based on the geographical dispersion of units. At the beginning of the generation of a unit, constraint and curtailment are pro-rated on their output. However, the availability of that unit might have risen but this is not taken into account in later periods. Rebalancing distributes curtailment and constraint across the group and considers changes of wind output as time progresses, while constraint and curtailment actions remain in place. According to the TSOs, rebalancing allows for an update to Constraint or Curtailment Setpoints to reflect the ability of each relevant unit to contribute to the Constraint or Curtailment target at that time. Rebalancing may result in higher setpoints for some units and lower setpoints for others. The energy balancing set point for a unit might also have moved and therefore the unit may be available to contribute in a new way.

For **Removal** of Constraint or Curtailment, the selected action is removed but may also cause other actions to be removed, as set out below:

- For Removal of Constraint, all active Constraint and Curtailment are removed (noting that any active Energy Balancing Setpoint will remain in place).
- For Removal of Curtailment, the Curtailment instruction is removed (noting that any active Constraint or Energy Balancing Setpoint will remain in place).

The RAs invite comments from industry on the definitions proposed by the TSOs on Energy Balancing and Rebalancing.

2.3 Parallel Constraints

In order to manage constraints, non-synchronous renewable generation units are grouped together depending on their effectiveness to alleviate those constraints. An individual non-synchronous renewable generation unit may be part of more than one constraint group, each with a different group MW target and resulting unit Constraint Setpoints. This is described in detail in the Wind Dispatch Tool Constraint Group Overview published on the EirGrid and SONI websites.

In addition to the above principles, Constraint Setpoints for an individual unit arising from different Constraint groups may be considered in parallel with each other. In this approach Constraint Setpoints for a unit are calculated independently of Constraint Setpoints for that unit from other Constraint groups. Where the calculated Constraint Setpoint for a unit from a particular Constraint group is higher than an existing Constraint Setpoint for that unit from another Constraint group, the setpoint issued to the unit is the lower setpoint.

3. Summary

Throughout the years, the RAs have conducted further reviews and published a number of papers to progress the implementation of the requirements outlined in the Clean Energy Package. This Consultation paper includes the proposed definitions by

the TSOs along with the worked examples which form a part of the Scheduling and Dispatch Programme.

The examples given in the appendix illustrate the interaction between different proposed changes, in particular the impact which rebalancing has. The RAs have no initial concerns; however, we invite stakeholders views on the question of Energy Balancing and Rebalancing as proposed by the TSOs in their definitions.

4. Next Steps

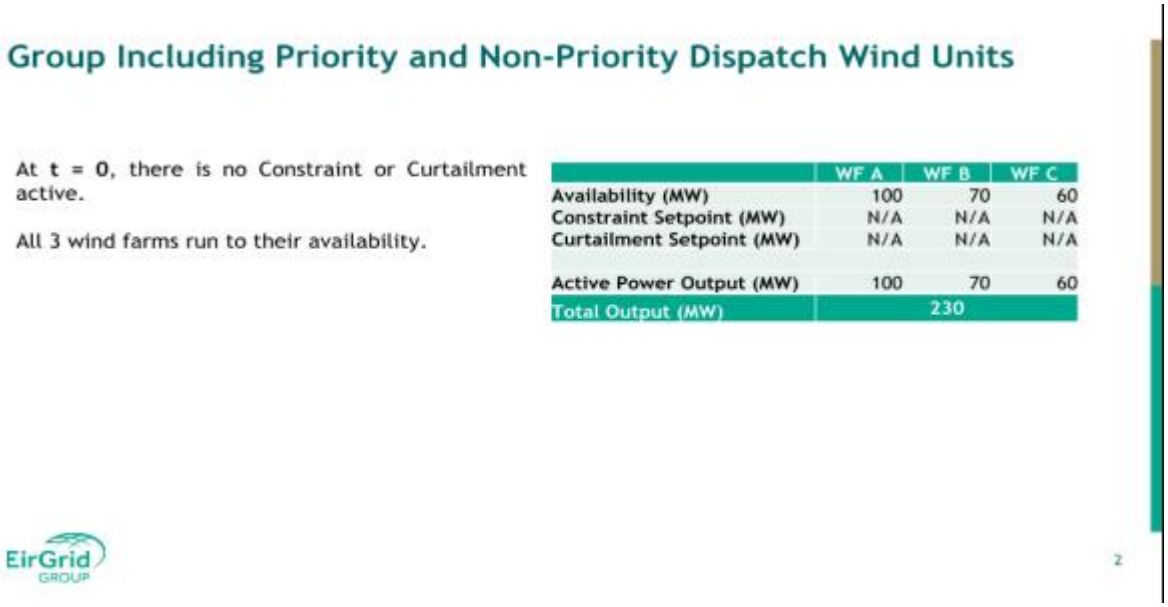
As discussed above, the RAs are inviting views on the definitions and processes proposed by the TSOs. Interested stakeholders are invited to respond to this consultation paper until 26 July 2024 and these responses should be submitted to schhetri@cru.ie and Bronagh.mckeown@uregni.gov.uk.

APPENDIX

Worked Examples

In the following section we have broken down the worked examples into three categories. The first example indicates how things are today, without any energy balancing and rebalancing. The second example indicates a scenario with energy balancing but without rebalancing. The third example shows a scenario with energy balancing and rebalancing (proposed by the TSOs).

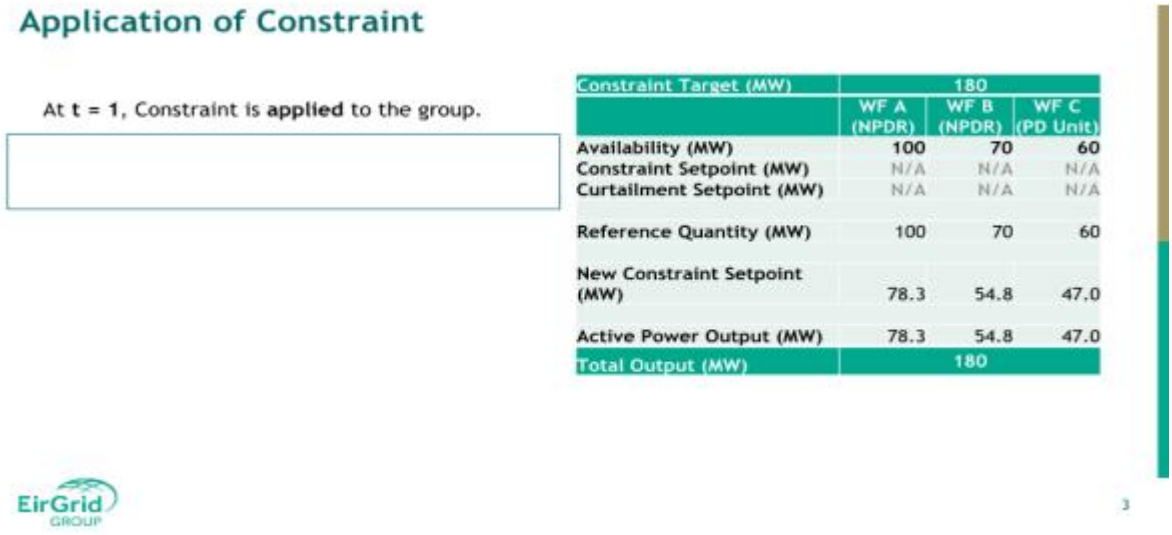
Worked Examples without Energy Balancing and without Rebalancing



As there is no curtailment and constraint at t=0 all the wind farms run to their availability.

Application

When applying Curtailment or Constraint the grid controller first determines the necessary reduction in output across the relevant group based on system conditions, giving the group MW target. Availability here is 230MW but the constraint is 180MW, therefore a 50MW reduction in output is required.



For application of Constraint

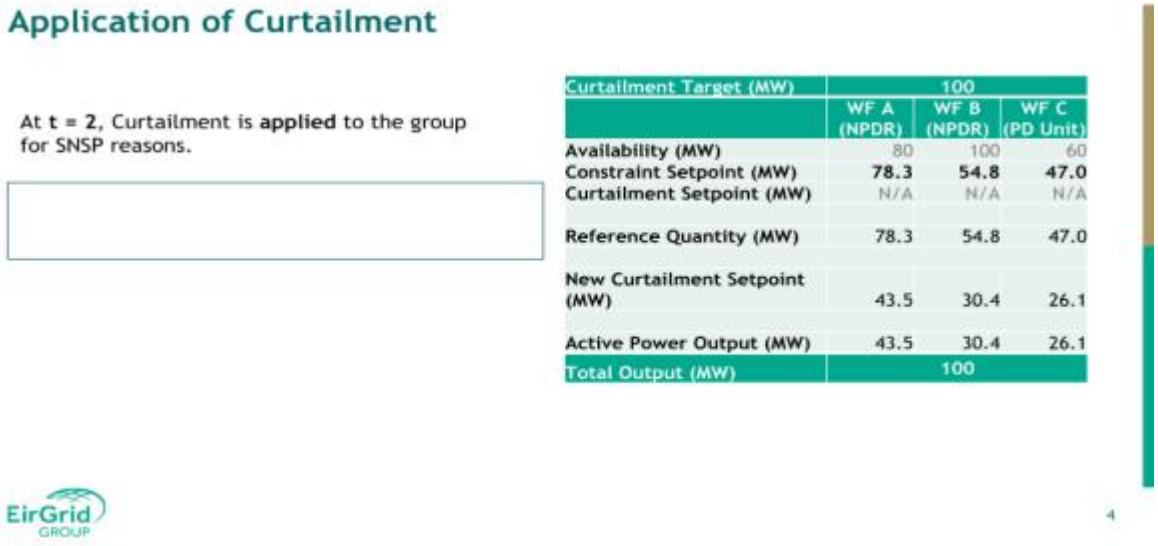
X = Reference Quantity = Availability

Y = Constraint Target

Z = Sum of Reference Quantities of the group to be constrained

Active Power Output = X * [Y/Z]

Thus, the active power output for wind farms (WFA, WFB and WFC) after being constrained is 78.3, 54.8 and 47.0 MW respectively.



For application of Curtailment

X= Reference Quantity= Availability after being constrained. Also, the availability for WFA has reduced to 80 and increased to 100 for WFB.

It is worth noting in this example that even though the availability has changed, all actions which follow come from when the first setpoint was calculated.

Y= Curtailment Target

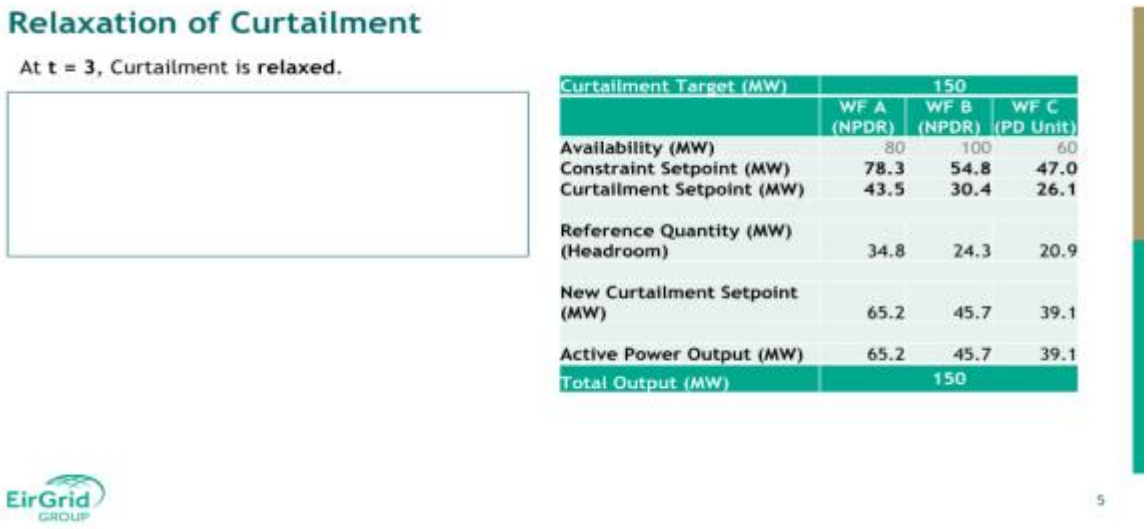
Z= Sum of Reference Quantities of the group to be curtailed

Active Power Output= X* [Y/Z]

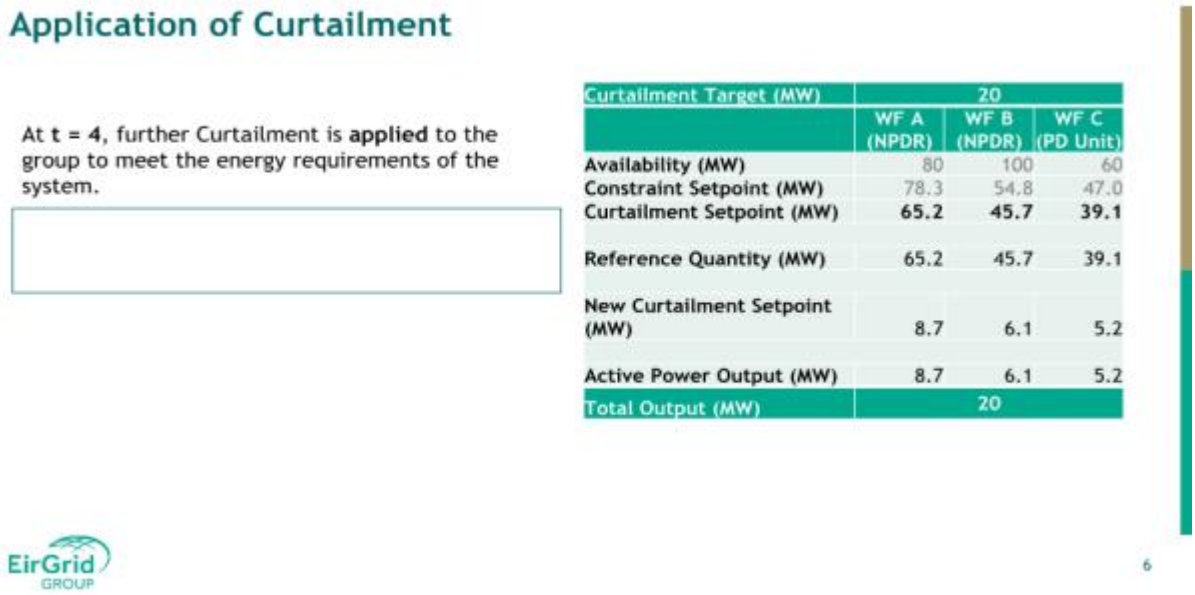
The active power output for wind farms (WFA, WFB and WFC) after being curtailed is 43.5, 30.4 and 26.1 MW respectively.

When Curtailment and Constraints are required simultaneously, the Constraint is applied first and then Curtailment.

Relaxation



In this example, the reference quantity or the headroom is the difference between the constraint setpoint and the curtailment setpoint. A curtailment target of 150MW from the reference quantity is applied to the group. This gives the new curtailment setpoint as 65.2MW, 45.7MW and 39.1MW respectively.



The reference quantity in this case is the minimum of availability, constraint setpoint and curtailment setpoint. A curtailment target of 20MW from the reference quantity is applied to the group. This gives the new curtailment setpoint of 8.7 MW, 6.1 MW and 5.2 MV respectively.

Removal

Since curtailment is removed, the active power output becomes the constraint setpoint. In general, when Curtailment and Constraints are active simultaneously, Curtailment is removed first and then Constraints.

Worked examples with Energy Balancing but without Rebalancing

In the previous section we were looking at the status quo that is, without any energy balancing and rebalancing. In this section we are looking at the status quo but with energy balancing added. The examples clarify the interaction between energy balancing and constraint and curtailment decisions taken by the TSO. Previously it was always in relation to availability or constraint and curtailment setpoint. Now the TSO decision-making will also account for any energy balancing setpoint that is applied.

Group Including Priority and Non-Priority Dispatch Wind Units

At **t = 0**, there is no Constraint or Curtailment active.

WF A and WF B do not have Priority Dispatch. They each have an Energy Balancing Setpoint selected on a merit order basis.

Energy Balancing Setpoints may be issued above a unit's availability provided that the price of the full volume is in merit.

WF C has Priority Dispatch. It does not receive Energy Balancing Setpoints. It runs to its availability.

	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	100	70	60
Energy Balancing Setpoint (MW)	120	50	N/A
Constraint Setpoint (MW)	N/A	N/A	N/A
Curtailment Setpoint (MW)	N/A	N/A	N/A
Active Power Output (MW)	100	50	60
Total Output (MW)	210		

EirGrid GROUP

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At t=0 there is no constraint and curtailment. As WFA and WFB do not have priority dispatch they have an energy balancing setpoint. WF C has Priority Dispatch and does not receive energy balancing setpoints.

Application

Application of Constraint

At **t = 1**, Constraint is **applied** to the group.

Constraint Target (MW)	180		
	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	**100**	70	**60**
Energy Balancing Setpoint (MW)	120	**50**	N/A
Constraint Setpoint (MW)	N/A	N/A	N/A
Curtailment Setpoint (MW)	N/A	N/A	N/A
Reference Quantity (MW)	100	50	60
New Constraint Setpoint (MW)	85.7	42.9	51.4
Active Power Output (MW)	85.7	42.9	51.4
Total Output (MW)	180		

EirGrid GROUP

3

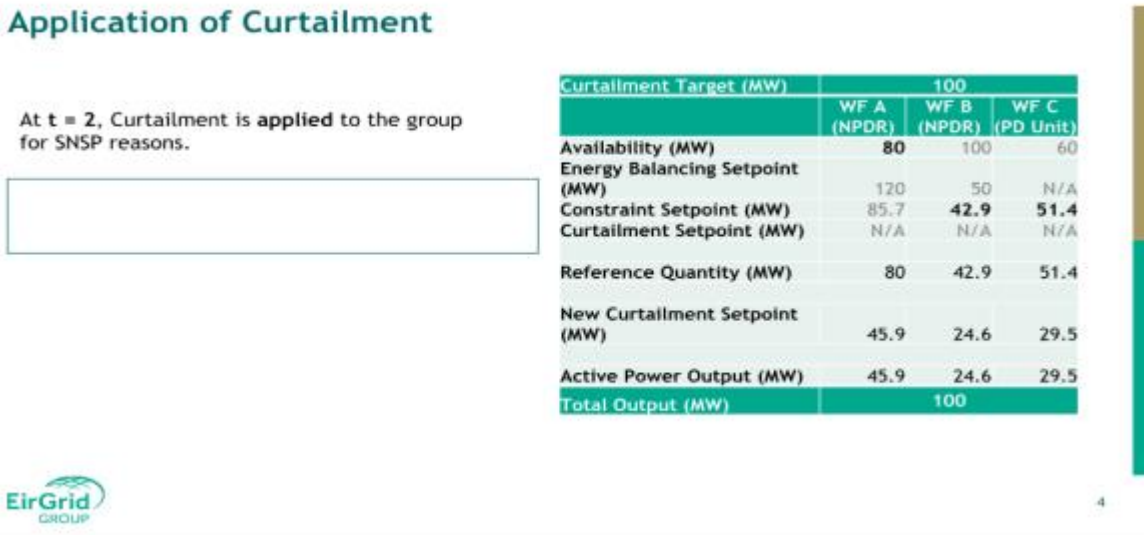
For application of Constraint

Unit setpoints for non-market-based application of Curtailment or Constraint within a group are calculated by the Wind Dispatch Tool as follows:

Unit Setpoint= Group MW Target * (Unit Reference Quantity/Sum of Reference Quantities)

Note that in the above example, whereas WFB is at the lower of the Energy Balancing Set point of 50MW, the reference quantity for WFA is taken to be 100MW instead of its Energy Balancing Setpoint of 120MW. Thus, the active power output for wind farms (WFA, WFB and WFC) after being constrained is 85.7MW, 42.9MW and 51.4 MW respectively.

In this example the TSOs have accepted an energy balancing action above the unit's availability. This is new and is a functionality that TSOs have included to give the National Control Centre some flexibility on balancing energy from such units.



Curtailment Target (MW)	100		
	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	80	100	60
Energy Balancing Setpoint (MW)	120	50	N/A
Constraint Setpoint (MW)	85.7	42.9	51.4
Curtailment Setpoint (MW)	N/A	N/A	N/A
Reference Quantity (MW)	80	42.9	51.4
New Curtailment Setpoint (MW)	45.9	24.6	29.5
Active Power Output (MW)	45.9	24.6	29.5
Total Output (MW)	100		

For application of curtailment

When the unit is regulating for frequency, nominal output is equal to the minimum of Available Active Power and any active setpoints. In this case as the minimum output for WFA is 80MW, the reference quantity is taken to be 80MW and the curtailment setpoint is calculated according to the above-mentioned algorithm.

Relaxation

Relaxation of Curtailment

At **t = 3**, Curtailment is **relaxed**.

Curtailment Target (MW)	150		
	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	80	100	60
Energy Balancing Setpoint (MW)	120	50	N/A
Constraint Setpoint (MW)	85.7	42.9	51.4
Curtailment Setpoint (MW)	45.9	24.6	29.5
Reference Quantity (MW) (Headroom)	34.1	18.3	21.9
New Curtailment Setpoint (MW)	68.8	36.9	44.2
Active Power Output (MW)	68.8	36.9	44.2
Total Output (MW)	150		

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For Curtailment, the maximum allowable output for relaxation is the minimum of (Available Active Power, Energy Balancing Setpoint, Constraint Setpoint), to the extent that each of these is active. As WFA and WFB have been curtailed already, the new reference quantity would be the difference between minimum (Availability and Curtailment Setpoint for WFA and Constraint Setpoint and Curtailment Setpoint for WFB)

Energy Balancing

Energy Balancing Actions on NPDR Units

At **t = 4**, Energy Balancing actions are taken on WF A and WF B on a merit order basis. Each of these units receives an Energy Balancing Setpoint of 0 MW.

	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	80	100	60
Energy Balancing Setpoint (MW)	120	50	N/A
Constraint Setpoint (MW)	85.7	42.9	51.4
Curtailment Setpoint (MW)	68.8	36.9	44.2
New Energy Balancing Setpoint (MW)	0	0	N/A
Active Power Output (MW)	0	0	44.2
Total Output (MW)	44.2		

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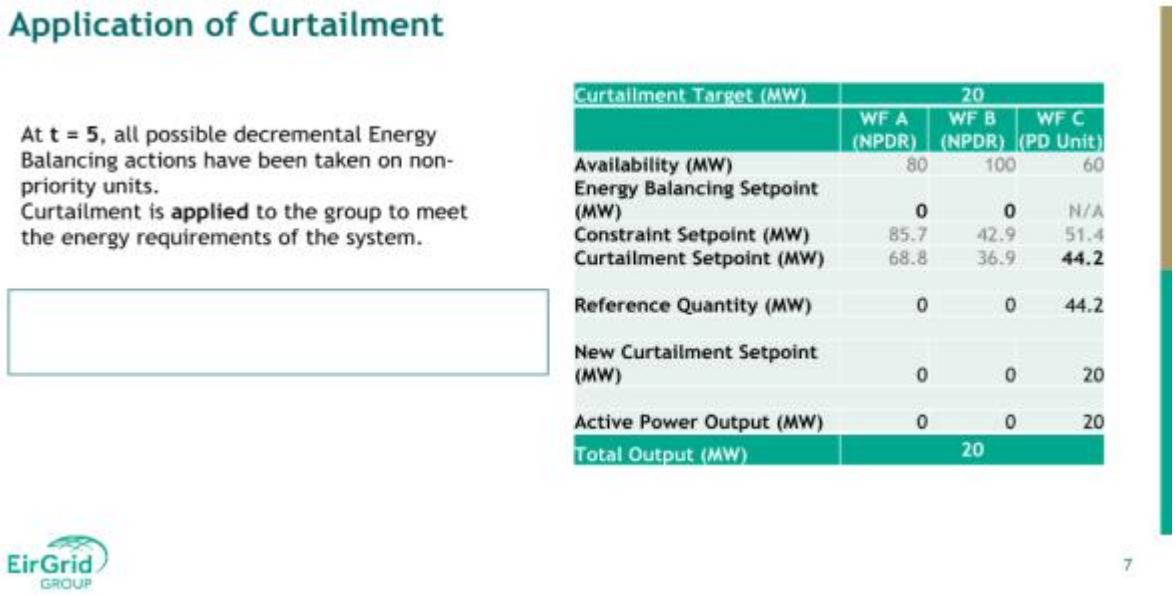
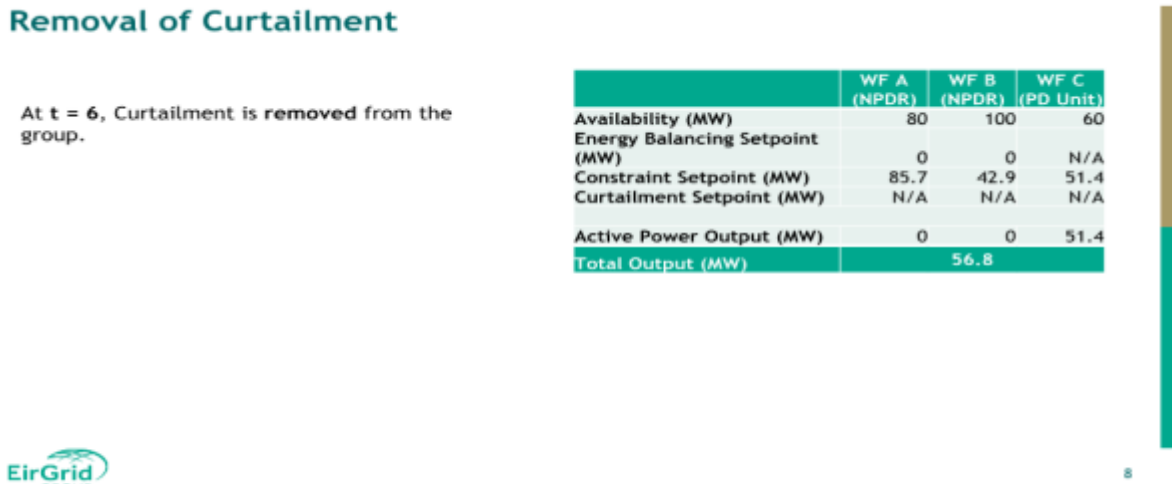
In this example, energy balancing actions are taken on WFA and WFB on a merit order basis and this receives an energy balancing setpoint of 0. As WFC does not have energy balancing actions and has priority dispatch, the active power output becomes 44.2 MW.



At t=5, all possible energy balancing actions have been taken on non-priority units and so the reference quantity for WFA and WFB becomes 0 each. The curtailment of target of 20MW is applied from the reference quantity of WFC which gives the total output of 20MW.

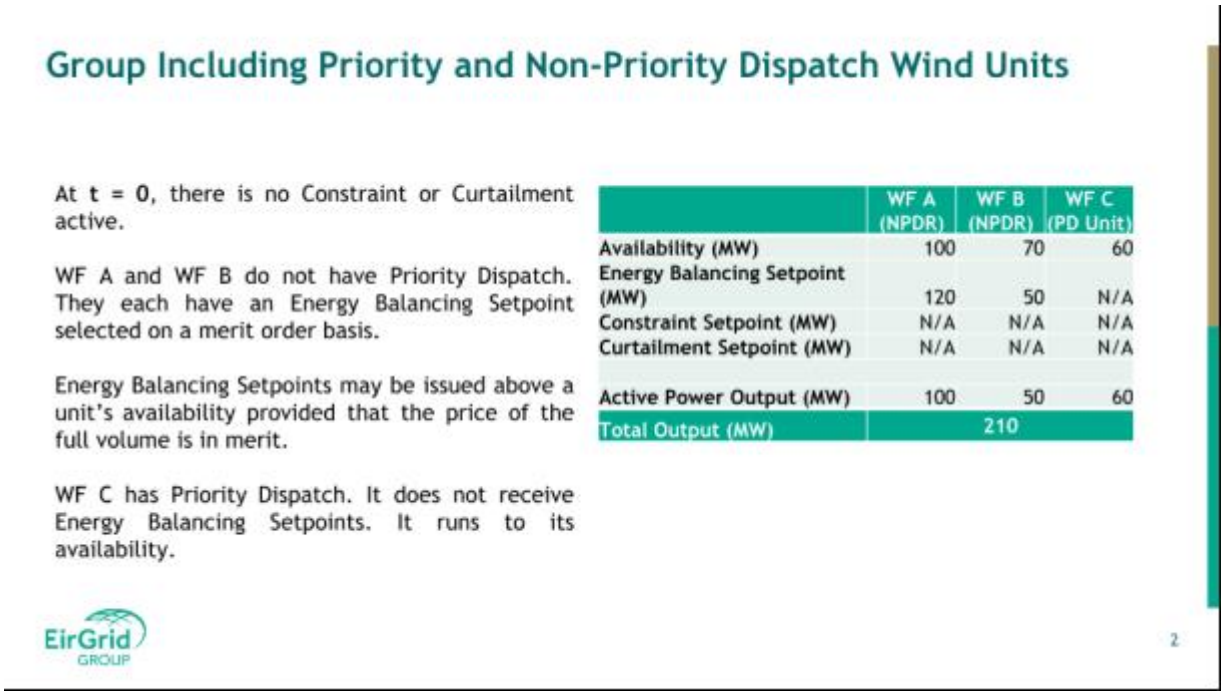
Removal



For Removal of Curtailment, the Curtailment instruction is removed (noting that any active Constraint or Energy Balancing Setpoint will remain in place).

Worked Examples with Energy Balancing and with Rebalancing

In this final section we are looking at the full TSO proposal in action, with energy balancing and rebalancing combined with the existing practice of the application of constraints and curtailment. The examples clarify the interaction between energy balancing and rebalancing with constraint and curtailment decisions taken by the TSO.



Group Including Priority and Non-Priority Dispatch Wind Units

At **t = 0**, there is no Constraint or Curtailment active.

WF A and WF B do not have Priority Dispatch. They each have an Energy Balancing Setpoint selected on a merit order basis.

Energy Balancing Setpoints may be issued above a unit's availability provided that the price of the full volume is in merit.

WF C has Priority Dispatch. It does not receive Energy Balancing Setpoints. It runs to its availability.

	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	100	70	60
Energy Balancing Setpoint (MW)	120	50	N/A
Constraint Setpoint (MW)	N/A	N/A	N/A
Curtailment Setpoint (MW)	N/A	N/A	N/A
Active Power Output (MW)	100	50	60
Total Output (MW)	210		

EirGrid GROUP

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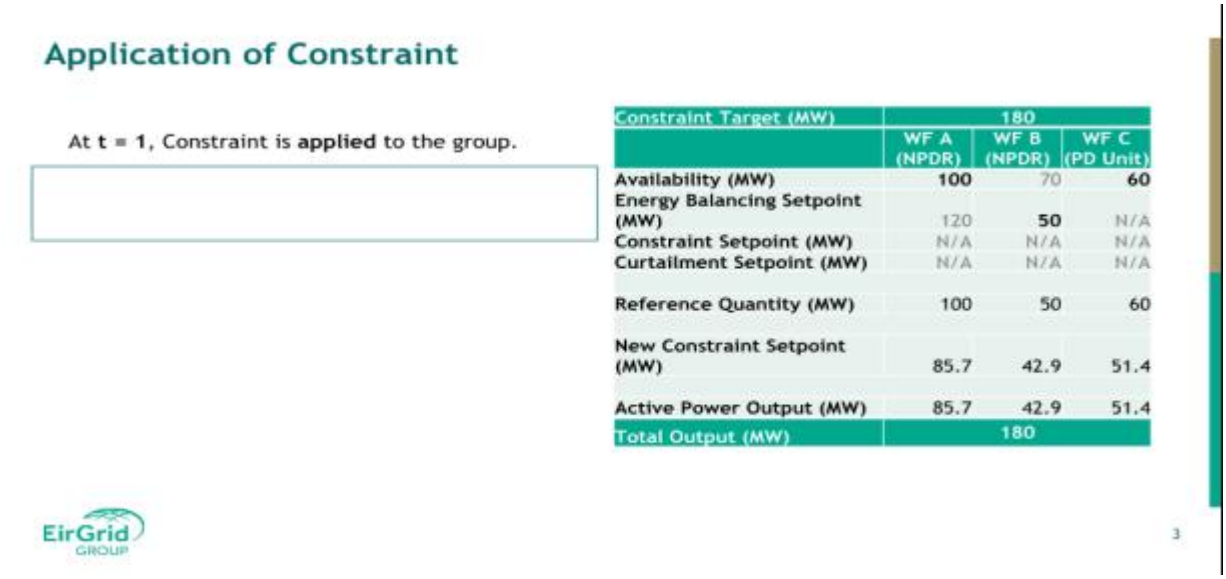
At t=0 there is no curtailment and constraint. WFA and WFB have energy balancing setpoint selected on a merit order basis. WFC does not have energy balancing setpoint.

Application

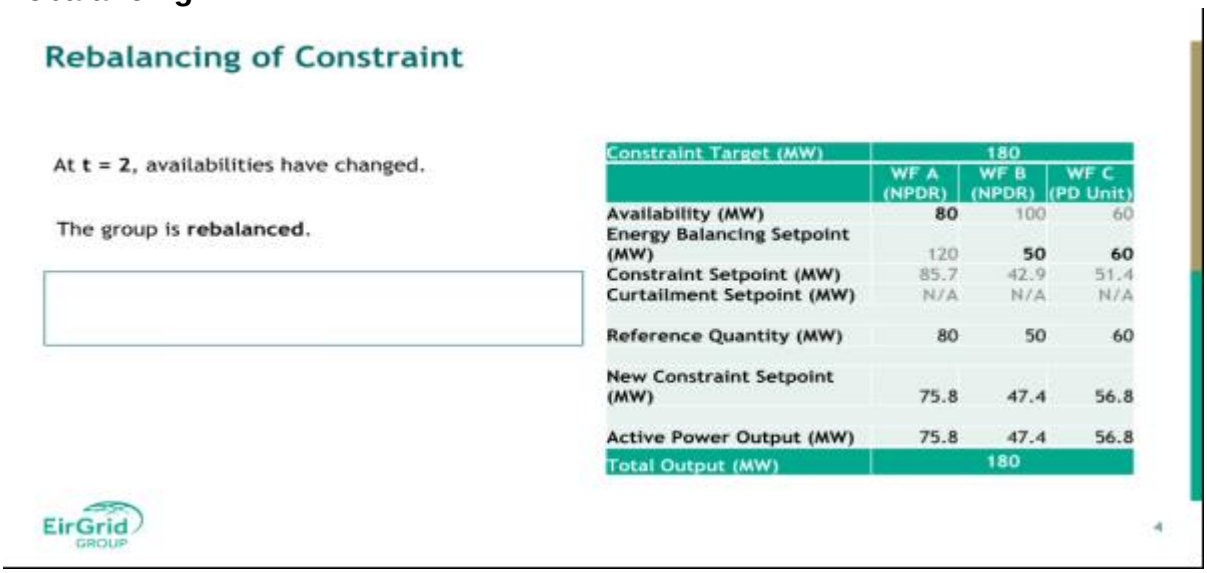


Unit setpoints for non-market-based application of Curtailment or Constraint within a group are calculated by the Wind Dispatch Tool as follows:

Unit Setpoint= Group MW Target * (Unit Reference Quantity/Sum of Reference Quantities)

Note that in the above example, the reference quantity for WFA is taken to be 100 instead of its Energy Balancing Setpoint. Thus, the active power output for wind farms (WFA, WFB and WFC) after being constrained is 85.7, 42.9 and 51.4 MW respectively.

Rebalancing



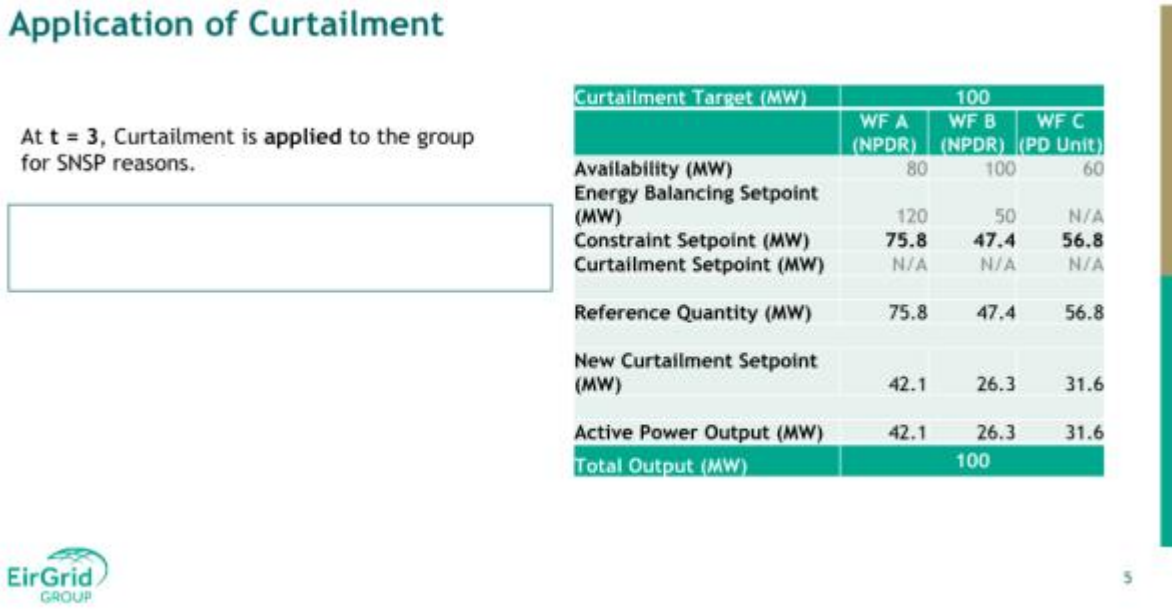
For Constraint:

- The maximum allowable output for rebalancing is the minimum of (Available Active Power, Energy Balancing Setpoint, Curtailment Setpoint), to the extent that each of these is active.
- Only units where the current Constraint Setpoint is below any active Curtailment Setpoint may be included in rebalancing of Constraint.

Unit setpoints for rebalancing of Curtailment or Constraint within a group are calculated by the Wind Dispatch Tool as follows:

Unit Setpoint= Group MW Target * (Unit Reference Quantity/Sum of Reference Quantities)

In this example, the setpoints for rebalancing are calculated on a pro-rata basis. So, the reference quantity for the group will be the minimum of availability, energy balancing setpoint and curtailment setpoint to the extent that each of these are active. Since the units have not been curtailed yet the reference quantity for WFA, WFB and WFC becomes 80, 50 and 60 MW respectively. The Constraint target of 180MW is applied across the group which gives the active power output of 75.8 MW, 47.4 MW, 56.8 MW, respectively.



Curtailment Target (MW)	100		
	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	80	100	60
Energy Balancing Setpoint (MW)	120	50	N/A
Constraint Setpoint (MW)	**75.8**	**47.4**	**56.8**
Curtailment Setpoint (MW)	N/A	N/A	N/A
Reference Quantity (MW)	75.8	47.4	56.8
New Curtailment Setpoint (MW)	42.1	26.3	31.6
Active Power Output (MW)	42.1	26.3	31.6
Total Output (MW)	100		

At t=3 a curtailment target of 100 is applied from the reference quantity across the group. The reference quantity is the minimum of availability, energy balancing setpoint

and constraint setpoint. The active power output for WFA, WFB and WFC becomes 42.1 MW, 26.3 MW and 31.6 MW respectively.

Relaxation of Curtailment

At **t = 4**, Curtailment is **relaxed**.

Relaxation setpoints are calculated using a different formula to that used for application or rebalancing. This is to ensure that no units receive a lower setpoint due to a relaxation action.

The reference quantity for relaxation is the headroom between the current setpoint and the next setpoint above (or availability if lower).

Curtailment Target (MW)	150		
	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	80	100	60
Energy Balancing Setpoint (MW)	120	50	N/A
Constraint Setpoint (MW)	75.8	47.4	56.8
Curtailment Setpoint (MW)	42.1	26.3	31.6
Reference Quantity (MW) (Headroom)	33.7	21.1	25.2
New Curtailment Setpoint (MW)	63.2	39.5	47.4
Active Power Output (MW)	63.2	39.5	47.4
Total Output (MW)	150		

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Curtailment cannot be relaxed above a Constraint Setpoint, but a Constraint can be relaxed above a Curtailment Setpoint. Any lower Curtailment Setpoint will be lifted in line with the new Constraint Setpoint.

Energy Balancing Actions on NPDR Units

At **t = 5**, Energy Balancing actions are taken on WF A and WF B on a merit order basis.
Each of these units receives an Energy Balancing Setpoint of 0 MW.

	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	80	100	60
Energy Balancing Setpoint (MW)	120	50	N/A
Constraint Setpoint (MW)	75.8	47.4	56.8
Curtailment Setpoint (MW)	63.2	39.5	47.4
New Energy Balancing Setpoint (MW)	0	0	N/A
Active Power Output (MW)	0	0	47.4
Total Output (MW)	47.4		

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In this example as the energy balancing actions are taken on WFA and WFB on a merit order basis, they receive a 0MW setpoint. As WFC does not have energy balancing actions, the total power output becomes 47.4 MW.

Application of Curtailment

At **t = 6**, all possible decremental Energy Balancing actions have been taken on non-priority units.
Curtailment is **applied** to the group to meet the energy requirements of the system.

Curtailment Target (MW)	20		
	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	80	100	60
Energy Balancing Setpoint (MW)	**0**	**0**	N/A
Constraint Setpoint (MW)	75.8	47.4	56.8
Curtailment Setpoint (MW)	63.2	39.5	**47.4**
Reference Quantity (MW)	0	0	47.4
New Curtailment Setpoint (MW)	0	0	20
Active Power Output (MW)	0	0	20
Total Output (MW)	20		

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The reference quantity in this example is 47.4 MW and the curtailment target of 20 MW is applied. The total output is 20 MW.

Removal of Curtailment

At **t = 7**, Curtailment is **removed** from the group.

	WF A (NPDR)	WF B (NPDR)	WF C (PD Unit)
Availability (MW)	80	100	60
Energy Balancing Setpoint (MW)	0	0	N/A
Constraint Setpoint (MW)	75.8	47.4	56.8
Curtailment Setpoint (MW)	N/A	N/A	N/A
Active Power Output (MW)	0	0	56.8
Total Output (MW)	56.8		

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At t= 7 as curtailment is removed, the total output is 56.8 MW as it’s the only remaining active set point above zero.