Wind Dispatch Tool Constraint Group Overview

28 February 2020

EIRGRID SONI

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CONTENTS

1 Introduction 4

2 Northern Ireland Constraint Groups 8

2.1 Constraint Group number 1 – NW Northern 9

2.2 Constraint Group number 2 – NW Southern 9

2.3 Constraint group number 3 – Oma-Dromore 10

2.4 Constraint group number 4 – All NI 10

3 Ireland North west Constraint Groups 11

3.1 North west Constraint Group 1: Letterkenny to Clogher Flows 12

3.2 North West Constraint Group 2: Corderry to Srananagh Flows 12

3.3 North West Constraint Group 3: Sligo to Flagford or Flagford 220/110 kV transformer Flows 13

3.4 North West Constraint Group 4: Carrick-on-Shannon to Arva or Sliabh Bawn to Lanesboro Flows. 14

4 Ireland West Constraint Groups 16

4.1 West Constraint Group 1: Lanesboro to Mullingar 17

4.2 West Constraint Group 2: Galway 110 kV Busbar Flows. 18

4.3 West Constraint Group 3: Cauteen 110 kV Station Voltage Stability 19

4.4 West Constraint Group 4: Lisheen to Thurles Flows 19

5 Ireland South West Constraint Groups 20

5.1 South West Constraint Group 1: Moneypoint 400/220 kV Transformer 2 21

5.2 South West Constraint Group 2: Rathkeale to Limerick Flows 23

5.3 South West Constraint Group 3: Glenlara to Ballynahulla Flows 23

5.4 South West Constraint Group 4: Ballylickey Voltage Stability 23

6 Ireland South East Constraint Groups 24

Appendix 1 Application of Constraint in the Wind Dispatch Tool 25

1 INTRODUCTION

OVERVIEW

Wind and solar generation is treated as priority dispatch (per SONI and EirGrid licences, SEM Committee decision SEM-11-062 and subsequent mods) however it is sometimes necessary to constrain or curtail its output to maintain system security. Constraints result from power flow limitations due to the topology and characteristics of the transmission network. Constraints are applied locally. Curtailment arises due to binding all-island system wide limits such as the System Non-Synchronous Penetration (SNSP) limit or minimum inertia levels. Curtailment is applied All-Island.

We use the Wind Dispatch Tool (WDT) in the TSOs' Control Centres to manage wind/solar constraints and curtailment in real time operation of the power system. The WDT allows the application of active power (MW) limits to the outputs of individual, controllable, wind/solar farms. While curtailment is applied globally to all wind/solar farms, constraints are applied to individual wind/solar farms or groups of wind/solar farms associated with the constraint. This document provides an overview of the main wind/solar constraint groups for Ireland and Northern Ireland that are currently defined in the WDT.

We plan to review the Wind Dispatch Tool constraint groups on a regular basis. We want to work in partnership with industry and welcome any feedback that you may have for consideration in future iterations. Please send feedback on this document to info@eirgrid.com or info@soni.ltd.uk.

CONSTRAINTS

Through real time monitoring of power flows and voltages, and modelling of the impact of contingency events, we determine the location and magnitude of generation constraints required to ensure EirGrid and SONI Operating Security Standards (OSS) are maintained.

The constraints set out in this report reflect the requirement for EirGrid and SONI to maintain power flows on transmission circuits within their thermal rating and to maintain voltage stability. Constraints can arise under a number of different scenarios:

- Intact Network – Even with all transmission circuits in service there can still be cases when the level of wind/solar generation exceeds the thermal rating of the transmission circuits in the area. These issues are known as 'base case' overloads. Flows on transmission circuits must be maintained below the normal continuous circuit ratings to allow for uncertainty and contingency events.
- Single Contingency – A contingency or tripping of a single item of transmission equipment (also known as a 'N-1' event) such as a transmission line, cable or transformer should not result in an unacceptable overload of any other item of transmission equipment. Flows on transmission circuits will be limited pre-contingency to ensure that the post-contingency flows are within acceptable limits.
- Planned Outage - During planned outages of transmission equipment, the transmission system must remain within limits in the 'base case' and for 'N-1' events. A contingency event that is coincident with a planned outage is known as a 'N-1-1' event.

Voltage stability issues can also arise under these scenarios. These tend to arise when large power flows cause voltages to sag and, if left unchecked, can result in voltage collapse. Restricting power flows resolves these issues.

CONSTRAINT GROUPS

In order to manage these constraints, wind/solar farms are grouped together depending on their effectiveness to alleviate constraints. The effectiveness is a measure of the change in wind/solar farm output relative to the change in the level of the constraint. The effectiveness of each wind/solar farm is a function of the topology of the transmission network.

Wind/solar farms connected at the same transmission station will generally have the same effectiveness in controlling power flows from that station so they are grouped together from a constraint management perspective. An exception to this arises if the transmission station is split or sectionalised, i.e. different wind/solar farms are selected to feed their output onto different parts of the transmission network.

Wind/solar farms connected at different transmission stations that are geographically/electrically spread apart will generally have different effectiveness levels in controlling power flows from that part of the transmission system. The grouping of these wind/solar farms is based on analysis of their effectiveness in managing the constraint. Wind/solar farms that can contribute to alleviating the constraint are included in the constraint group. Wind/solar farms that do not (or marginally) contribute to alleviating the constraint are excluded from the constraint group.

APPLICATION OF CONSTRAINT GROUPS IN THE WIND DISPATCH TOOL

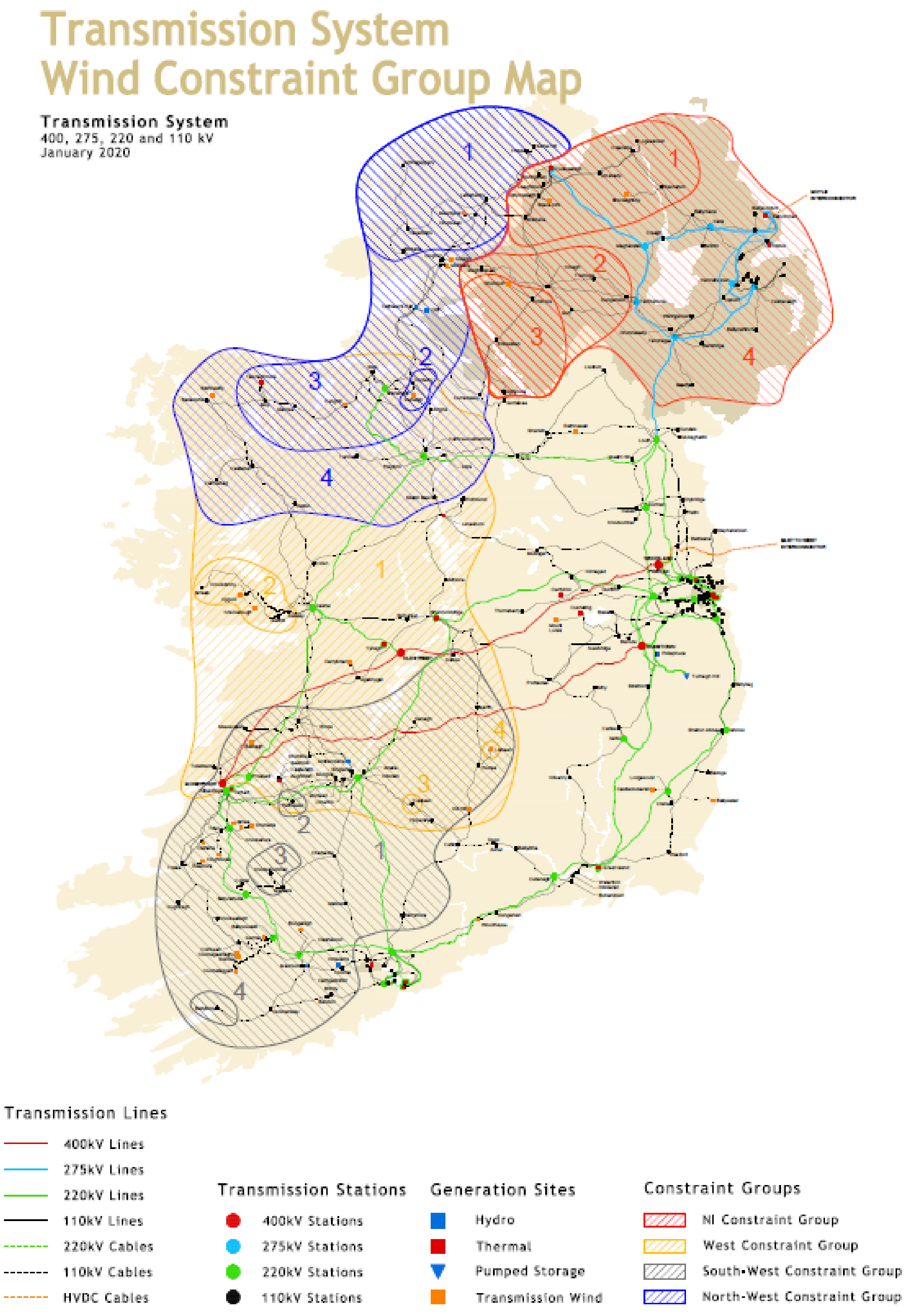
For each constraint group, all wind/solar farms with Controllability Category 2[1] connected to the transmission stations in that group (either connected directly to the transmission station or connected via the local distribution network) are included in the predefined constraint groups in the WDT.

Constraint groups are predefined in the WDT to allow for their quick application in real time system operations.

Based on real time monitoring and analysis of the power system, we determine the need to apply and remove constraints. To apply a constraint, the appropriate predefined group is selected and a MW reduction level specified in the WDT. The WDT then calculates the MW setpoint for each wind/solar farm in the group and issues individual MW setpoints to the control system of each wind/solar farm. A description of how these MW setpoints are determined in the WDT is set out in Appendix 1.

The following presents a geographic illustration of the main constraint groups in the WDT.

[1] http://www.eirgridgroup.com/site-files/library/EirGrid/Wind%20Farm%20Controllability%20Categorisation%20Policy.pdf


Transmission System
Wind Constraint Group Map
Transmission System
400, 275, 220 and 110 kV
January 2020
Transmission Lines
400kV Lines
275kV Lines
220kV Lines
110kV Lines
220kV Cables
110kV Cables
HVDC Cables
Transmission Stations
400kV Stations
275kV Stations
220kV Stations
110kV Stations
Generation Sites
Hydro
Thermal
Pumped Storage
Transmission Wind
Constraint Groups
NI Constraint Group
West Constraint Group
South-West Constraint Group
North-West Constraint Group

The following sections outline in more detail these constraint groups predefined in the WDT. Outages of transmission circuits and changes to the topology of the transmission system (new transmission circuits) will change the effectiveness of wind/solar farms to manage constraints. As a result, modifications will be made to existing constraint groups, new constraint groups will be created and no longer relevant constraint groups will be removed as power system conditions change.

The geographic spread of each constraint group is illustrated and a table of the transmission stations with controllable wind connected is provided.

2 NORTHERN IRELAND CONSTRAINT GROUPS

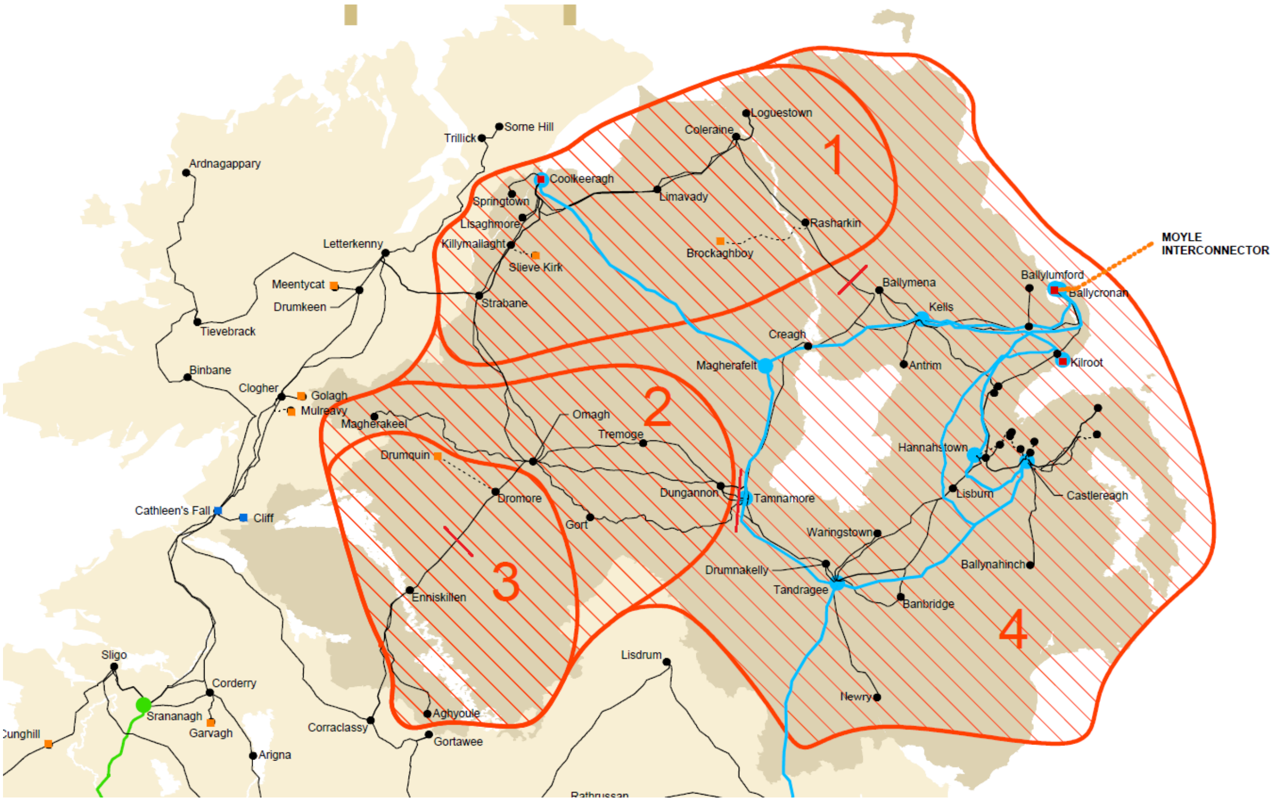


Figure 1: Northern Ireland Geographical Constraint Groups

2.1 Constraint Group number 1 – NW Northern

This constraint group is used when the largest potential overload is on the Kells-Rasharkin 110 kV line.

This constraint group includes all generation connected to the following transmission nodes (comprising approximately 450 MW of renewable generation):

Station	**Notes**
Brockaghboy	
Coleraine	
Coolkeeragh	
Killimallaght	
Limavady	
Lisaghmore	
Loguestown	
Rasharkin	
Slieve Kirk	
Strabane	

2.2 Constraint Group number 2 – NW Southern

This constraint group is used when the largest potential overloads are between Omagh and Tamnamore (Tremoge – Tamnamore 110 kV and Dungannon – Tamnamore 110 kV overloads).

This constraint group includes all generation connected to the following transmission nodes:

Station	**Notes**
Aghyoule	
Drumquin	
Dungannon	
Enniskillen	
Gort	

Magherakeel	
Omagh	
Tremoge	

This constraint group includes all generation connected to the following transmission nodes (comprising approximately 610 MW of renewable generation):

2.3 Constraint group number 3 – Oma-Dromore

This constraint group is needed to relieve potential overloads between Dromore and Omagh 110 kV.

This constraint group includes all generation connected to the following transmission nodes (comprising 186 MW of renewable generation):

Station	**Notes**
Aghyoule	
Drumquin	
Enniskillen	

2.4 Constraint group number 4 – All NI

This constraint group is required to manage flows on the 275/220 kV tie-lines between Tandragee 275 kV station and Louth 220 kV Station. It includes all controllable renewable Northern Ireland generation.

3 IRELAND NORTH WEST CONSTRAINT GROUPS

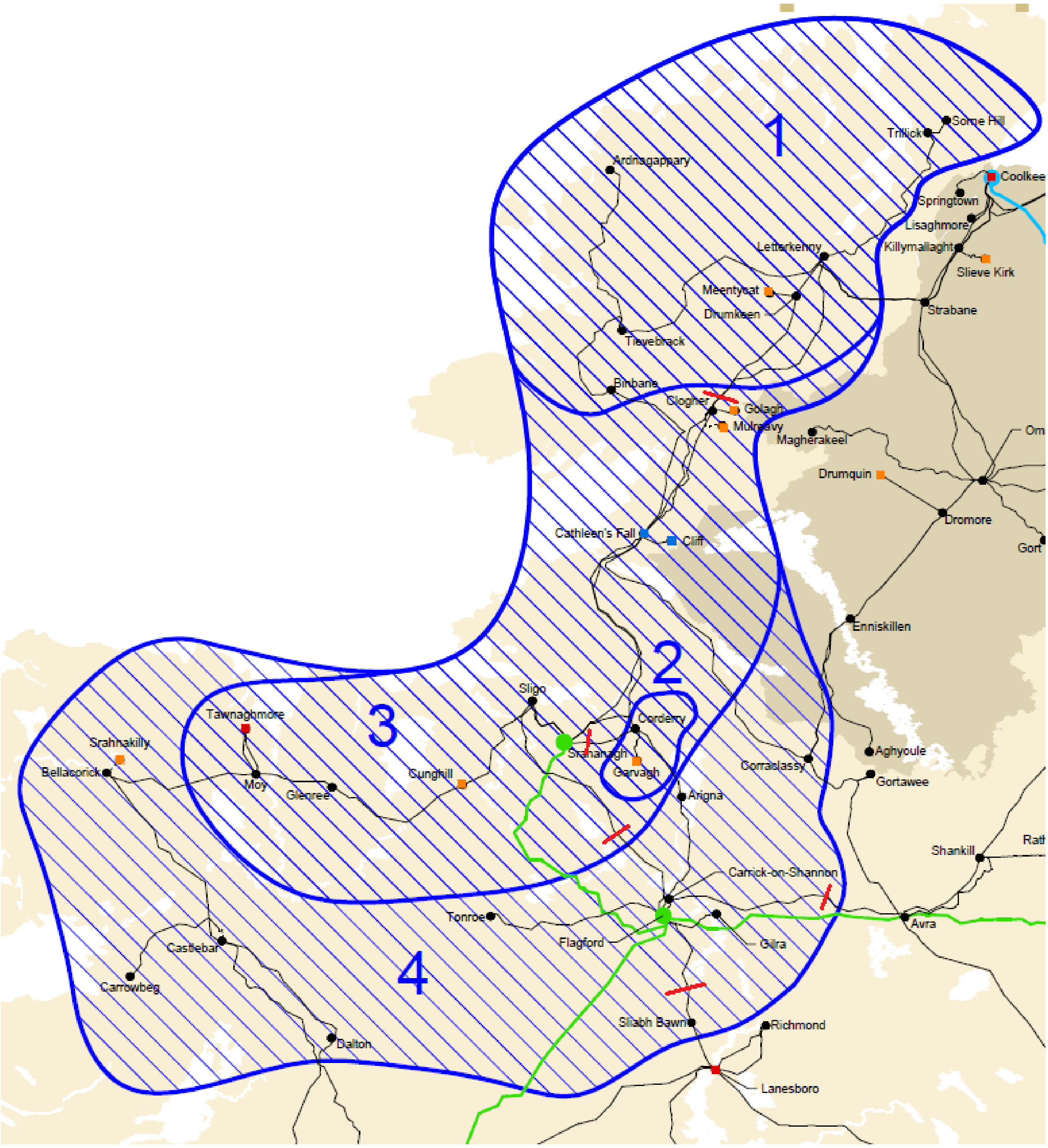


Figure 2: North West Geographical Constraint Groups

3.1 North west Constraint Group 1: Letterkenny to Clogher Flows

This constraint group is used when power export from North Donegal is limited for the post contingency risk of overloads on the Clogher-Drumkeen 110 kV circuit or the Clogher-Golagh T section of the Clogher-Golagh-Letterkenny 110 kV circuit (or for excessive basecase loading under outage conditions). A constraint of this group is generally only required in low to medium load conditions.

Station	Notes
Meentycat	
Sorne Hill	
Trillick	
Ardnagappary	Excluded during outages of Letterkenny-Tievebrack 110 kV circuit
Binbane	Excluded during outages of Letterkenny-Tievebrack or Binbane-Tievebrack 110 kV circuits

3.2 North West Constraint Group 2: Corderry to Srananagh Flows

This constraint group is used due to limitations on the Corderry-Srananagh 110 kV circuit (in the Corderry to Srananagh direction) during high outputs of wind/solar connected at Corderry and Garvagh 110 kV stations.

In order to protect this circuit a pre-contingency constraint needs to be applied to this group to mitigate against the risk of tripping the Arigna-Carrick-on-Shannon-Corderry 110 kV circuit.

Station	Notes
Corderry	
Garvagh	

3.3 North West Constraint Group 3: Sligo to Flagford or Flagford 220/110 kV transformer Flows

This constraint group is used due to limitations on the Flagford-Sligo 110 kV circuit when there is an excessive export of wind/solar from the North West Donegal/Sligo/Mayo region which is not backed off by large wind/solar output from the Midlands and West regions.

A constraint is required to protect this circuit against the potential risk of the loss of the 220 kV circuit accommodating large flows from Srananagh to Flagford out of the region.

Station	**Notes**
Cunghill	Excluded during outages of Cunghill-Sligo 110 kV circuit
Corderry	
Garvagh	
Sligo	
Moy	Excluded during outages of Cunghill-Sligo, Cunghill-Glenree or Glenree-Moy 110 kV circuits
Glenree	Excluded during outages of Cunghill-Sligo or Cunghill-Glenree 110 kV circuits
Cathaleen’s Fall	
Ardnagappary	
Binbane	
Mulreavy	
Sorne Hill	
Trillick	
Meentycat	

In order to minimise constraints on the 110 kV network in the North West, Flagford is often sectionalised at 110 kV in which the busbar is often split to restrict through flow on the busbar and force increased flows onto the 220 kV network which is capable of transferring more power to the east.

When Flagford is split at 110 kV the binding network issue that requires a constraint in the region moves from limitations on Flagford-Sligo to limitations on the Flagford 220/110 kV transformer, T2102, again for the loss of Flagford-Srananagh 220 kV circuit.

This could prompt coupling of Flagford again at 110 kV and constrain for limitations on Flagford-Sligo 110 kV or constrain this same constraint group for limitations on the Flagford 220/110 kV transformer, T2102.

3.4 North West Constraint Group 4: Carrick-on-Shannon to Arva or Sliabh Bawn to Lanesboro Flows.

This constraint group is used due to limitations on the Arva-Carrick-on-Shannon 110 kV circuit when there is an excessive export of wind/solar from the entire West and North West Regions to the East of the Network.

A pre-constraint is required to protect this circuit against the potential risk of the loss of a section of a parallel path out of the region from Cathaleen’s Fall to Arva.

Sectionalising of the Network is often carried out in order to greatly reduce constraints in the region. This can involve splitting Flagford or Arva 110 kV stations or a combination of both. This puts greater stress on the Arva-Carrick-on-Shannon 110 kV circuit making this condition binding.

Station	**Notes**
Cunghill	
Corderry	
Garvagh	
Sligo	
Moy	
Glenree	
Cathaleen’s Fall	
Ardnagappary	
Binbane	
Mulreavy	
Sorne Hill	
Trillick	

Meentycat	
Srahnakilly	
Castlebar	
Dalton	
Sliabh Bawn	

When the wind/solar in the West and Midlands is much less than the wind/solar in the North West as per the binding condition for constraint group 3, there is a risk that the Lanesboro-Sliabh Bawn 110 kV circuit will get overloaded for the loss of Flagford-Srananagh 220 kV circuit particularly when Flagford is coupled at 110 kV

4 IRELAND WEST CONSTRAINT GROUPS

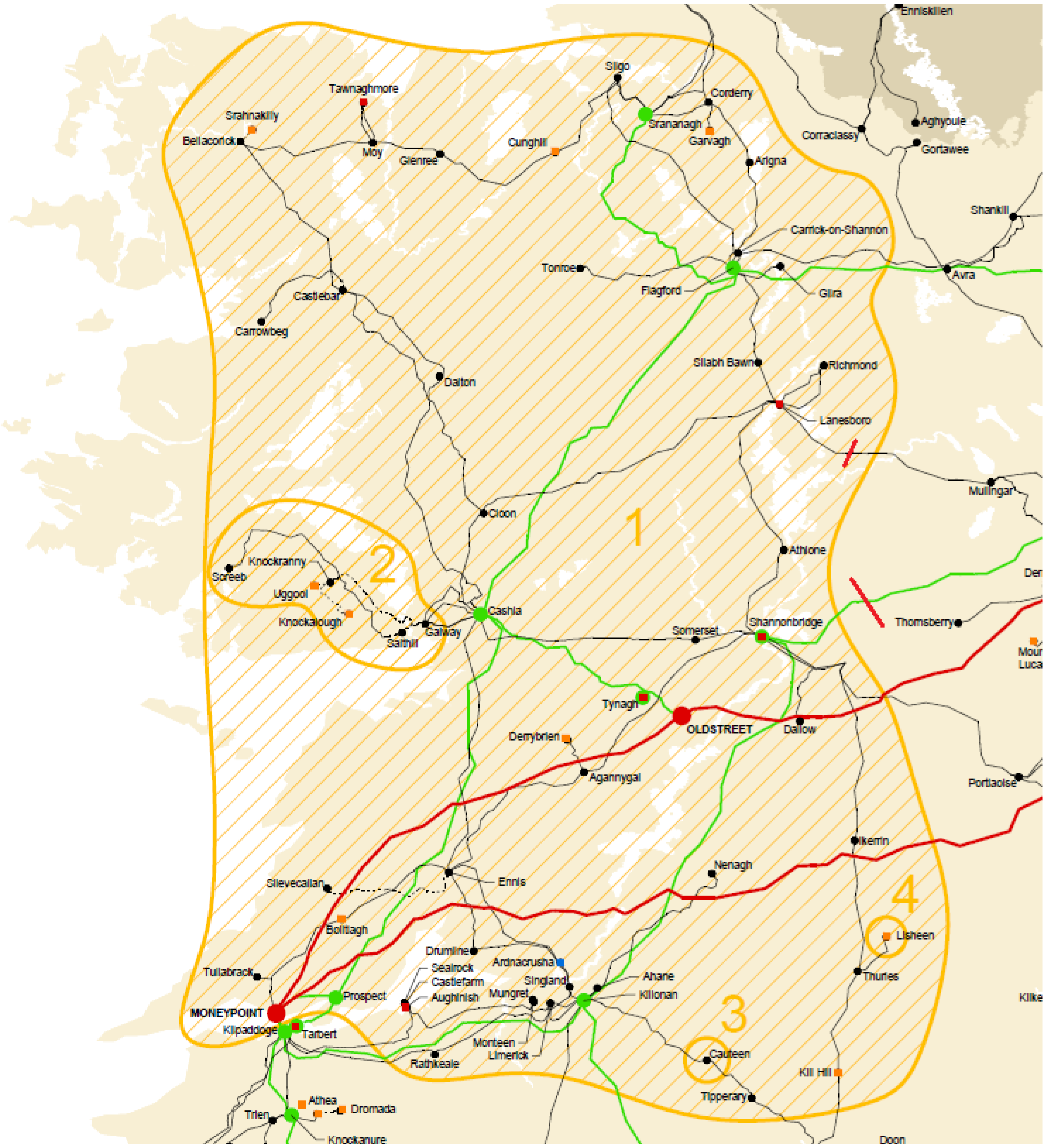


Figure 3: West Geographical Constraint Groups

4.1 West Constraint Group 1: Lanesboro to Mullingar

This constraint group is used due to limitations on the Lanesboro-Mullingar 110 kV circuit when there is an excessive export of wind/solar from the entire West Region to the East of the Network.

A pre-constraint is required to protect this circuit against the potential risk of the loss of a path to the 400 kV network from Oldstreet to Tynagh to transfer power from the West to the East of the network.

Sectionalising of the Network is often carried out in order to greatly reduce constraints in the region. This can involve opening the Kinnegad 110 kV circuit breaker in Mullingar 110 kV station or splitting the Flagford busbar at 110 kV.

Station	**Notes**
Sliabh Bawn	
Moy	
Glenree	
Tawnaghmore	
Srahnakilly	
Castlebar	
Dalton	
Knockalough	
Uggool	
Salthill	
Cunghill	
Corderry	
Garvagh	
Sligo	
Ardnacrusha	
Tullabrack	
Moneypoint	
Booltiagh	

Slieve Callan	
Rathkeale	
Derrybrien	
Dallow	
Ikerrin	
Thurles	
Kill Hill	
Lisheen	
Cauteen	

For the loss of the link from the 220 kV to 400 kV network from Tynagh to Oldstreet there is also a risk of excessively overloading the Maynooth-Shannonbridge 220 kV circuit. This is often alleviated by sectionlising Maynooth at 220 kV, isolating the Shannonbridge 220 kV cubicle from the higher load north Dublin bound feeders, Woodland and Gorman.

If this is possible it transfers the binding condition for constraints onto the Lanesboro-Mullingar 110 kV circuit discussed above. The optimum condition to reduce constraints is a combination of both sectionalising actions discussed here and to constrain for issues on the Lanesboro-Mullingar 110 kV circuit.

If Maynooth-Shannonbridge 220 kV circuit is the binding condition, the same constraint group can be used to alleviate this.

4.2 West Constraint Group 2: Galway 110 kV Busbar Flows.

This constraint group is used due to base case limitations on sections of the Galway 110 kV busbar.

All contingency issues are mitigated against via the operation of a busbar monitoring Special Protection Scheme (SPS) in Galway 110 kV station.

Station	**Notes**
Uggool	
Knockalough	
Salthill	

4.3 West Constraint Group 3: Cauteen 110 kV Station Voltage Stability

This constraint group is used due to post-contingency voltage stability at Cauteen 110 kV for the loss of Cauteen-Tipperary 110 kV circuit.

Voltage stability is maintained at Cauteen 110 kV station for the loss of the Cauteen-Killonan 110 kV circuit through the operation of a Special Protection Scheme (SPS).

Station	Notes
Cauteen	

4.4 West Constraint Group 4: Lisheen to Thurles Flows

This constraint group is used to manage base case flows on the Lisheen-Thurles 110 kV circuit when there is high outputs of wind/solar out of Lisheen and under high temperature conditions.

Station	Notes
Lisheen	

5 IRELAND SOUTH WEST CONSTRAINT GROUPS

Figure 4: South West Geographical Constraint Groups

5.1 South West Constraint Group 1: Moneypoint 400/220 kV Transformer 2

This constraint group is used due to limitations on the Moneypoint 400/220 kV Transformer 2 (T4202) when exporting wind/solar from Kerry, north onto the 400 kV network.

[14 October 2021: Please note the following update]

With the return of Moneypoint 400/220 kV Transformer 1 (T4201) from long term forced outage the South West Constraint Group 1: Moneypoint 400/220 kV Transfer 2 will still be required. This is to protect against excessive N-1 loading on Moneypoint 400/220 kV Transformer T4202 above its emergency overload capability for the loss of Moneypoint 400/220 kV Transformer T4201 in normal operation

This region is heavily sectionalised at times in order to minimise wind/solar constraints in the region by a combination of the following actions: splitting Moneypoint 220 kV, splitting Kilpaddoge 220 kV, splitting Knockanure at 110 kV, splitting Trien at 110 kV, splitting Boggeragh at 110 kV, splitting Glenlara 110 kV station and opening the Tarbert 110 kV circuit breaker in Tralee 110 kV station.

[08 April 2020: Please note that this South West Constraint Group 1 has been temporarily updated – please refer to this document for the updated version]

Station	Notes
Tralee	
Dromada	
Athea	
Kilpaddoge	
Trien	
Reamore	
Clahane	
Cloghboola	
Oughtragh	
Knockearagh	
Glanlee	
Cordal	
Garrow	

Coomagearlaghy	
Boggearagh	
Ardnacrusha	
Tullabrack	
Moneypoint	
Booltiagh	
Slieve Callan	
Rathkeale	
Barrymore	
Macroom	
Bandon	
Dunmanway	
Charleville	
Glenlara	
Ballylickey	
Derrybrien	
Dallow	
Ikerrin	
Thurles	
Kill Hill	
Lisheen	
Cauteen	

5.2 South West Constraint Group 2: Rathkeale to Limerick Flows

This constraint group is used due to limitations on the Rathkeale-Limerick 110 kV circuit when exporting wind/solar from Kerry when there is less midlands and west wind/solar to back off flows transferring the export across the 110 kV network.

Pre-contingency constraints are required to protect the circuit for the risk of tripping the Kilpaddoge-Tarbert 220 kV circuit.

Station	Notes
Rathkeale	

5.3 South West Constraint Group 3: Glenlara to Ballynahulla Flows

This constraint group is used due to basecase limitations on the Ballynahulla - Glenlara 110 kV circuit.

Glenlara 110 kV station is normally split (sectionalised) meaning that this constraint only impacts a subset of wind/solar farms at Glenlara.

Station	Notes
Glenlara	Impacts wind/solar farms connected via the A1 110 kV busbar (Dromdeeveen and Mauricetown).
Knockacummer	

5.4 South West Constraint Group 4: Ballylickey Voltage Stability

This constraint group is used due to the risk of voltage instability at Ballylickey 110 kV station if its connection point at Dunmanway is tailed post contingency under high wind/solar conditions.

Station	Notes
Ballylickey	

6 IRELAND SOUTH EAST CONSTRAINT GROUPS

Binding constraints in the South East region are rare and the region is generally managed by a combination of conventional generation re-dispatch, system sectionalising or Special Protection Scheme (SPS) action.

APPENDIX 1 APPLICATION OF CONSTRAINT IN THE WIND DISPATCH TOOL

The level of constraint/curtailment is determined by monitoring real time power system conditions. Through real time modelling of contingency (N-1) events and system limits we identify what generation is effective and what level of reduction in generation is required to ensure that system security standards are maintained. The application, updating and removal of constraints/curtailment is a dynamic process that considers: the variability in wind production, the ability of other non-wind units to respond to changes in energy production and the often interacting nature of constraints and curtailment.

In both constraint and curtailment scenarios, we use the Wind Dispatch Tool (WDT) to implement the required constraint/curtailment levels on individual wind/solar farms. The WDT determines the active power (MW) set point for each wind/solar farm based on: a) selection of the wind/solar farms impacting the constraint (or all wind/solar farms if a system wide limit) as determined by the control room operator and b) the total constraint/curtailment level (MW) required as specified by the control room operator. The following sections describe how the individual wind/solar farm active power (MW) set-points for constraint/curtailment are calculated in the WDT.

Wind Dispatch Tool Active Power Set Point Calculation Methodology

The wind/solar farm active power set point calculation in the WDT accounts for the impact of wind/solar farms providing frequency response, the control category of wind/solar farms and SEMC wind farm constraint groups. In order to illustrate the key aspect of the calculation we have provided a simplified example below that ignores the additional complexities introduced by the items specified above. Further details on the impact of frequency response are included at the end of this appendix.

In this example, four wind/solar farms form a defined constraint group although the same logic would apply to application to global curtailment. The constraint on each wind/solar farm is applied pro-rata using the following formula:

Wind/Solar Farm “A” dispatch set point = Wind/Solar Farm “A” Active Power output – (group total constraint down required)*(Wind/Solar Farm “A” Active Power output /Sum of Wind/Solar Farm Active power output of all wind/solar farms in the operator defined group)

Time T, applying a constraint

Total Availability of Wind/Solar Farm Group	400 MW	Total Output of Wind/Solar Farm Group	400 MW	Wind/Solar Constraint Down Required	100 MW

	Wind/Solar Farm A	**Wind/Solar Farm B**	**Wind/Solar Farm C**	**Wind/Solar Farm D**
Permissible Capacity	100 MW	150 MW	250 MW	200 MW
Available Active Power	50 MW	100 MW	150 MW	100 MW
Active Power Output	50 MW	100 MW	150 MW	100 MW
Dispatch Instruction	50 – (100*50/400) = 37.5 MW	100 – (100*100/400) = 75 MW	150 – (100*150/400) = 112.5 MW	100 – (100*100/400) = 75 MW
Constraint	12.5 MW (25%)	25 MW (25%)	37.5 MW (25%)	25 MW (25%)

So the 100 MW constraint is applied in proportion to the active power output of each wind/solar farm which, for the initial application of the constraint, is also equal to the available active power of each wind/solar farm.

If the wind/solar farms are further dispatched down as the constraint/curtailment becomes worse this will always be pro-rata based on the wind/solar farm actual output and does not consider the changing availability of the wind/solar farm.

Time T+1, additional wind/solar available, further constraint

Total Availability of Wind/solar Farm Group	530 MW	Total Output of Wind/solar Farm Group	300 MW	Wind/solar Constraint Down Required	100 MW

	Wind/solar Farm A	Wind/solar Farm B	Wind/solar Farm C	Wind/solar Farm D
Permissible Capacity	100 MW	150 MW	250 MW	200 MW
Available Active Power	100 MW	80 MW	200 MW	150 MW
Active Power Output	37.5 MW	75 MW	112.5 MW	75 MW
Dispatch Instruction	37.5 – (100*37.5/300) = 25 MW	75 – (100*75/300) = 50 MW	112.5 – (100*112.5/300) = 75 MW	75 – (100*75/300) = 50 MW
Constraint	75 MW (75%)	30 MW (37.5%)	125 MW (62.5%)	100 MW (66.67%)

When a constraint/curtailment is being released, the amount being released pro-rata on each wind/solar farm will be relative to the dispatch head room available on each wind/solar farm. This head room will be based on the point in time difference between the available active power (for constraints) or the minimum of available active power and last binding constraint set point (for curtailments) to the active power output of the wind/solar farm. Although a release will use the wind/solar farms point in time available active power in the calculation, this will only be used to distribute the amount of constraint/curtailment being released more evenly among the wind/solar farms given updated availabilities as opposed to distributing the group total constraint/curtailment at the point of time more evenly across all wind/solar farms given updated availabilities.

Time T+2, relaxing the constraint

Total Availability of Wind/solar Farm Group	530 MW	Total Output of Wind/solar Farm Group	200 MW	Wind/solar Constraint Relaxed by	100 MW

	Wind/solar Farm A	Wind/solar Farm B	Wind/solar Farm C	Wind/solar Farm D
Permissible Capacity	100 MW	150 MW	250 MW	200 MW
Available Active Power	100 MW	80 MW	200 MW	150 MW
Active Power Output	25 MW	50 MW	75 MW	50 MW
Head Room	100-25 = 75 MW	80-50 = 30 MW	200-75 = 125 MW	150-50= 100 MW
Dispatch Instruction	25 + (100*75/330) = 47.7 MW	50 + (100*30/330) = 59.1 MW	75 + (100*125/330) = 112.9 MW	50 + (100*100/330) = 80.3 MW
Constraint	52.3 MW (52.3%)	20.9 MW (26.1%)	87.1 MW (43.6%)	69.7 MW (46.4%)

Impact of Frequency Response

In 2017, the WDT calculation methodology was updated to account for Frequency response.

Instead of the active power output used in the calculation we use a frequency adjusted power output but the same trend in the calculation output is seen. This calculation aims to both evenly distribute a constraint/curtailment at a point in time and also account for wind/solar farms that are not contributing to frequency response as expected. Additional constraints or curtailments to this wind/solar farm group will again not take into consideration updated wind/solar farm availabilities. For curtailment/constraint releases wind/solar farm availabilities will be used to assist in the relative pro-rata release of the constraint/curtailment but again as above will not re-distribute the total group constraint/curtailment based on the new availabilities at that point in time.

The frequency adjusted power output is calculated as follows;

1. The nominal power output of all wind/solar farms assuming no frequency response is approximated
   a. This is assumed to be the available active power or
   b. The previous dispatch set point
2. The difference between all active and nominal outputs is calculated for all wind/solar farms in the constraint group and this is deemed the groups full frequency response
3. The nominal output of each wind/solar farm is adjusted based on a pro-rata distribution of the group's frequency response relative to the permissible capacity of each wind/solar farm in the group. This is termed the frequency adjusted power output of each wind/solar farm.