

Grid Code Compliance Testing

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Operational Services and Performance

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Content

- Purpose of Grid Code Testing
- Roles of the Customer & TSO
- Testing Overview
- Testing timelines
- Operational Certificate
- Testing Timelines
- Grid Code Testing Known Issues



Purpose of Grid Code Testing

- **Ensure safe, secure and economic operation of the Power System**
- **Demonstrate** compliance with the Grid Code
 - Issue Operations Certificate
- Test true **capabilities** of the Generator unit at Commissioning stage and throughout lifetime of unit
 - Contract for Ancillary Services
 - Address non-compliance via remedy and/or derogation
- Assess the level of impact on **other users** and the **performance** of the Power **System**



Customers

- Users connecting to the System must undergo Grid Code Compliance Testing.
- The following connections undergo this similar process:
 - All Transmission Connected WFPS Generation
 - DSO WFPS connections 5MW or more
- CDGU Generating Units testing review completed.



Role - Customer

- Notify TSO Commissioning and Proposed modifications to Installed Plant as early as possible
- Organise and Demonstration of Compliance as applicable with Grid Code
- Development of necessary Test Procedures and signoff at least 10 days in advance of testing.
- Submission of the test profile & Outages to control@eirgrid.com & SEMO
- Request for ESBI Commissioner as applicable (TEM)
- Completion of Test Reports with Test data



Data Requirements - Customer

- Turbine Data Sheets & Models
- Commissioning Programme
- Completion Certificates (wiring / pre & post energisation signals and control Check)
- Operational Readiness Confirmation
- Installed Plant confirmation
- Raw data for completed tests
- Test reports & respond to queries
- Registered Characteristics
- Operational Certificate



Agreeing a Test

- Standard list of tests to the Customer (available online)
- Discussion of testing methodology
 - Alternatives are assessed and agreed
- Grid Code Tests conducted with normal generator control settings applied.
- Compliance must be demonstrated while operating within EPA licence limits.
- Submit Test Request & agreed test procedure to Generator_testing@eirgrid.com with test date.

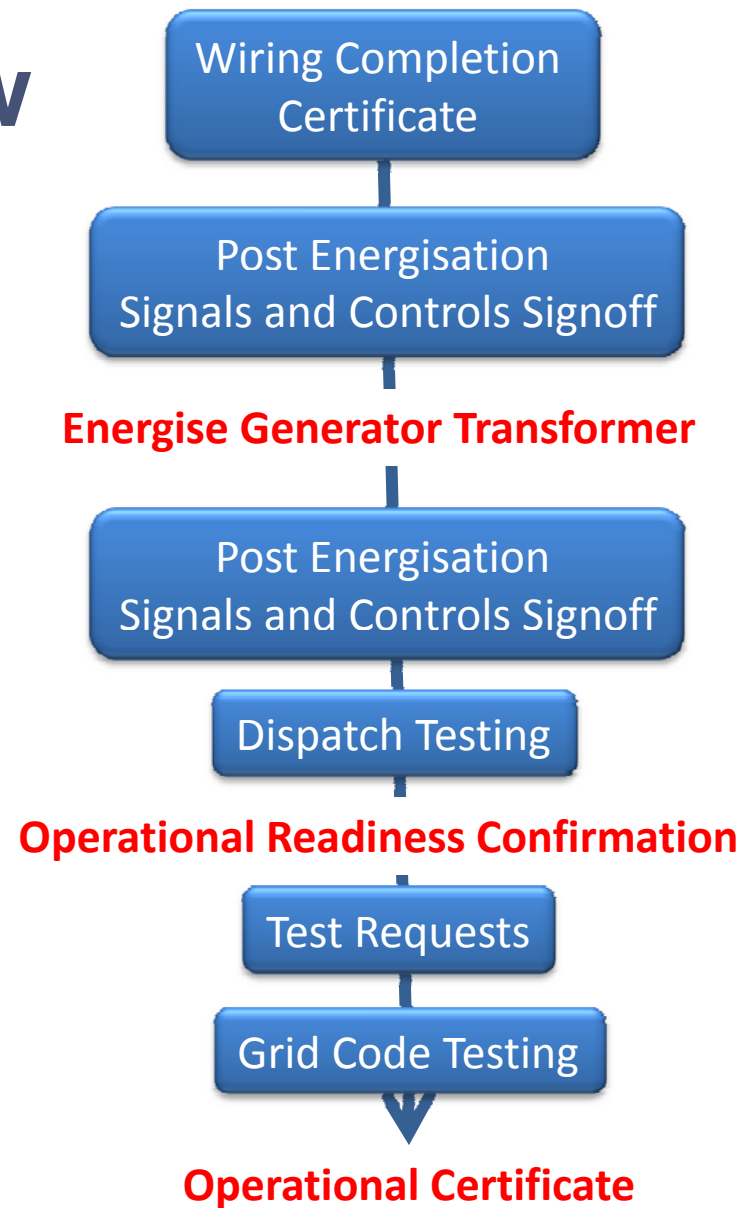


Role - TSO

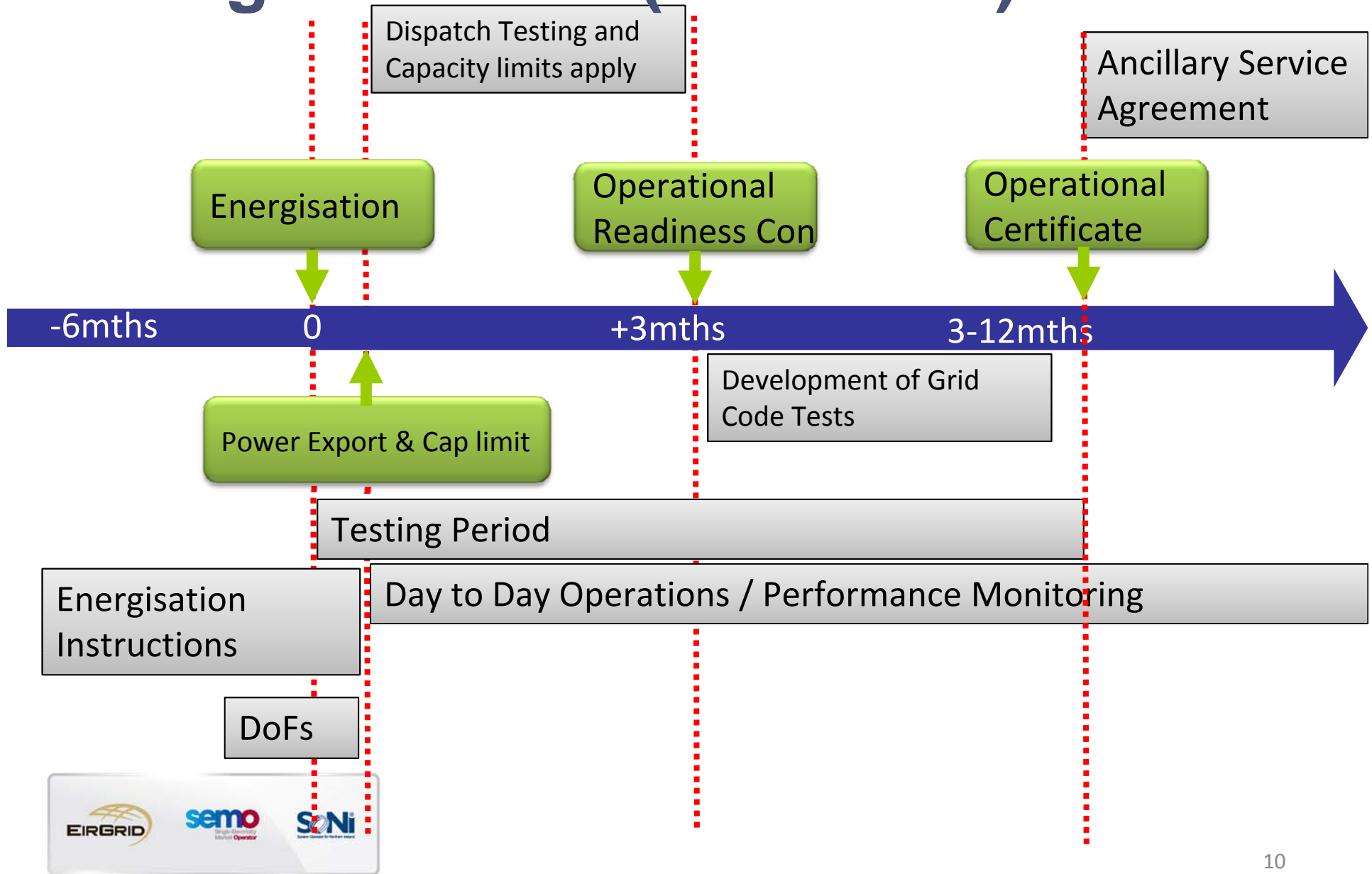
- Develop Signal Lists
- Co-ordination of testing (Dispatch and GCCT)
- Issue Operational Readiness Confirmation
- Agree Test Procedures for TSO Requirements
- Onsite Witnessing of tests
- Ensure Communications are clear between Responsible Operators and NCC
- Recommend for Operational Certificate
- Recommend for Ancillary Services with test report
- Handover to Per. Monitoring and Customer Relations



Testing Overview



Testing Timelines (indicative)



Operational Certificate

- Issued by TSO on successful completion of Grid Code Compliance testing.
 - Statement on tests completed successfully
 - Derogations which are required to address known non-compliances
 - Ongoing monitoring of unit
 - Conditions for revocation of Ops Cert



Operational Certificate

- An Operational Certificate triggers:
 - under the terms of the customer’s Connection Agreement, the **MEC Capacity Bond** can be released and, if applicable, ‘**Firm Access**’ applied;
 - under the terms of the Ancillary Service Agreement receive **Ancillary Service payments**;
 - All relevant sections in TSO informed and PCA parameters provided



Grid Code Testing - Known Issues

- Signalling and Controllability Issues
- Reliable Forecasting and Scheduling of testing
- OEM travelling from abroad to carry out testing
- Test Failures due to lack of Grid Code Knowledge
- Completion of testing within acceptable time lines
- Continued non-compliance of legacy Wind Farm Power Stations
- Notification to TSO of registered characteristic changes
- Meeting Reactive Power Requirements
- Appreciation of TSOs role to test multiple units in parallel
- Retrospective application of new Grid Code Modifications



Dispatch Testing

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November 19th 2012

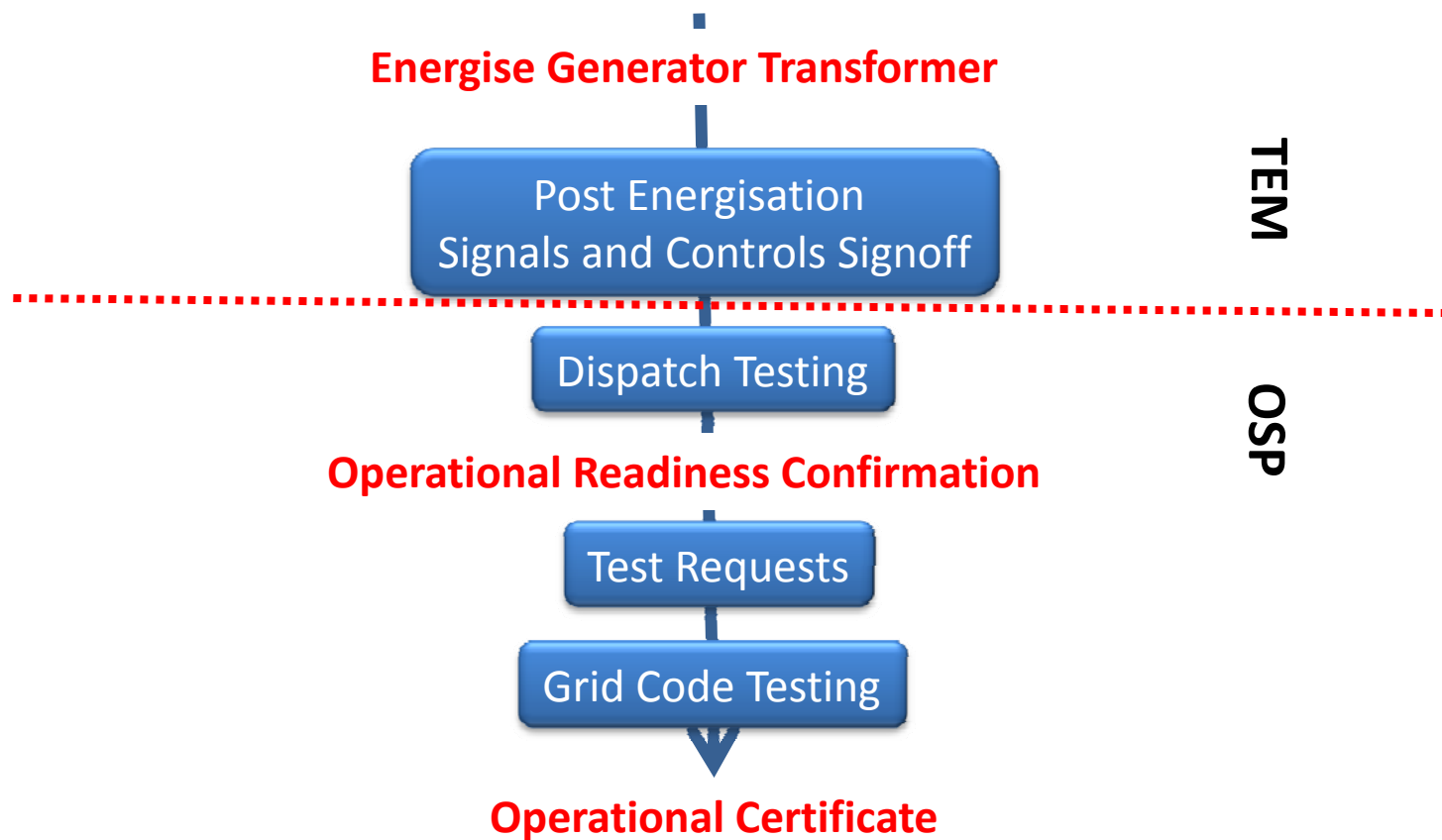


Dispatch Testing

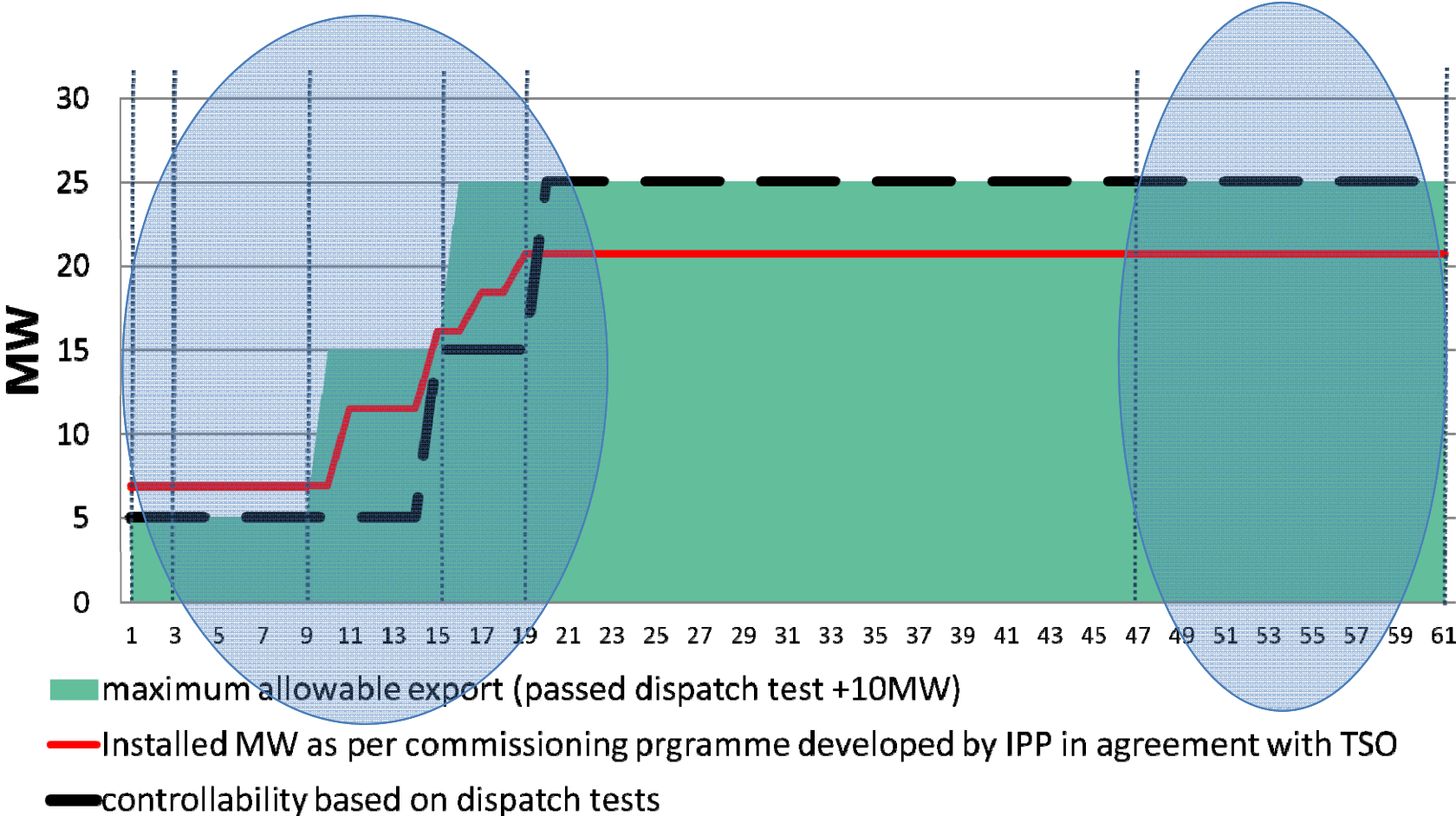
- Testing Overview
 - Commissioning Programme
 - Post Energisation Signals and Controls signoff (3 party)
 - Capacity Limits
- Dispatch Testing
 - Controllability Requirements
 - Examples of Pass / Fail
 - Reporting
 - Operational Readiness Confirmation
- Categories of Controllability
 - Moving Categories (iii) to (ii)
 - Reference to Performance Monitoring
- Scheduling and Wind Forecasting



Testing Overview



Sample Commissioning Program



Controllability Requirements

One key test

1. The WFPS Active Power Control System is compliant during real time operation and/or during ongoing performance monitoring and testing of the WFPS.

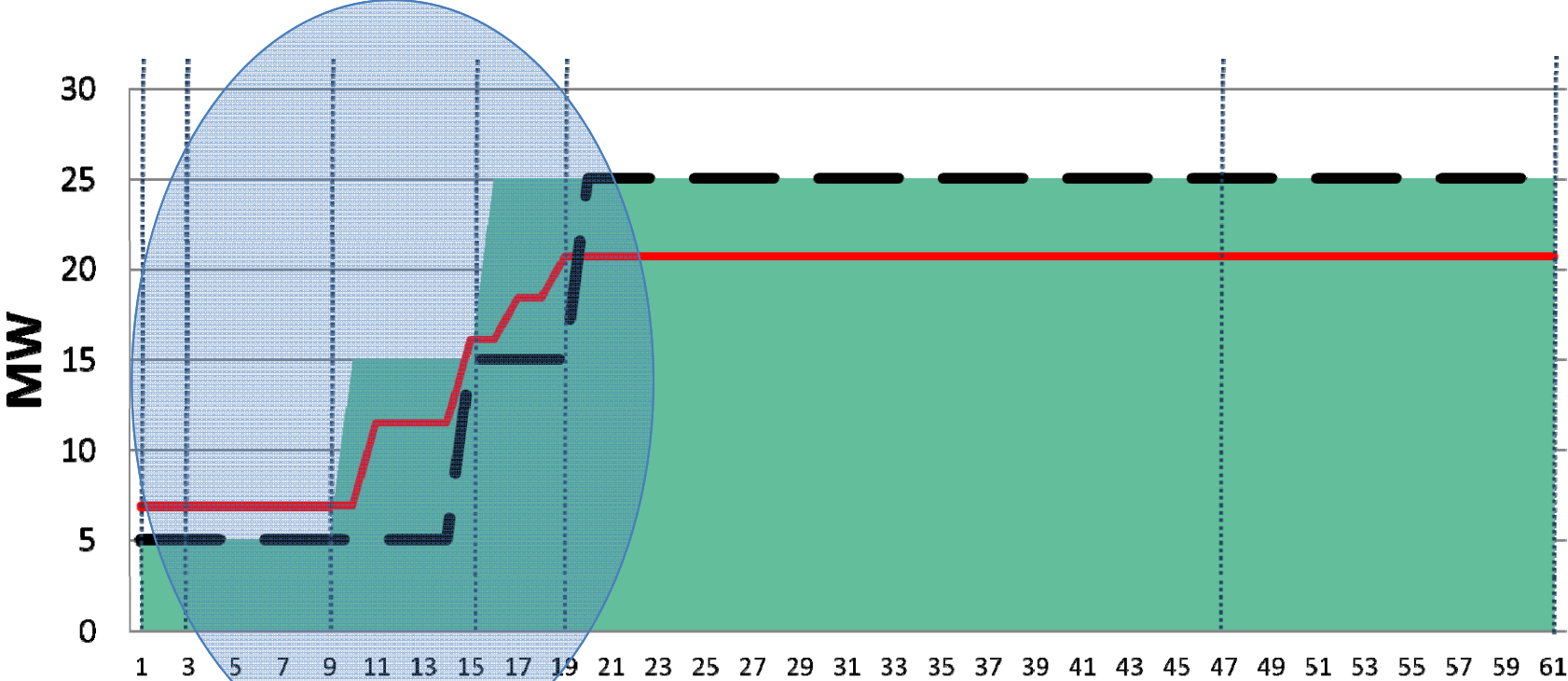


Test 1- Active Power Control System

- Turn the active power control on or off through SCADA with acknowledgement from the WFPS;
- Series of MW setpoints issued to the WFPS with acknowledgement from the WFPS;
- WFPS active power control responds within 10 seconds with the required ramp rates to the required dispatch instruction(s);
- Required dispatch instruction set point should be maintained as a maximum until a new set point is issued from the TSO or the active power control is switched off by the TSO.



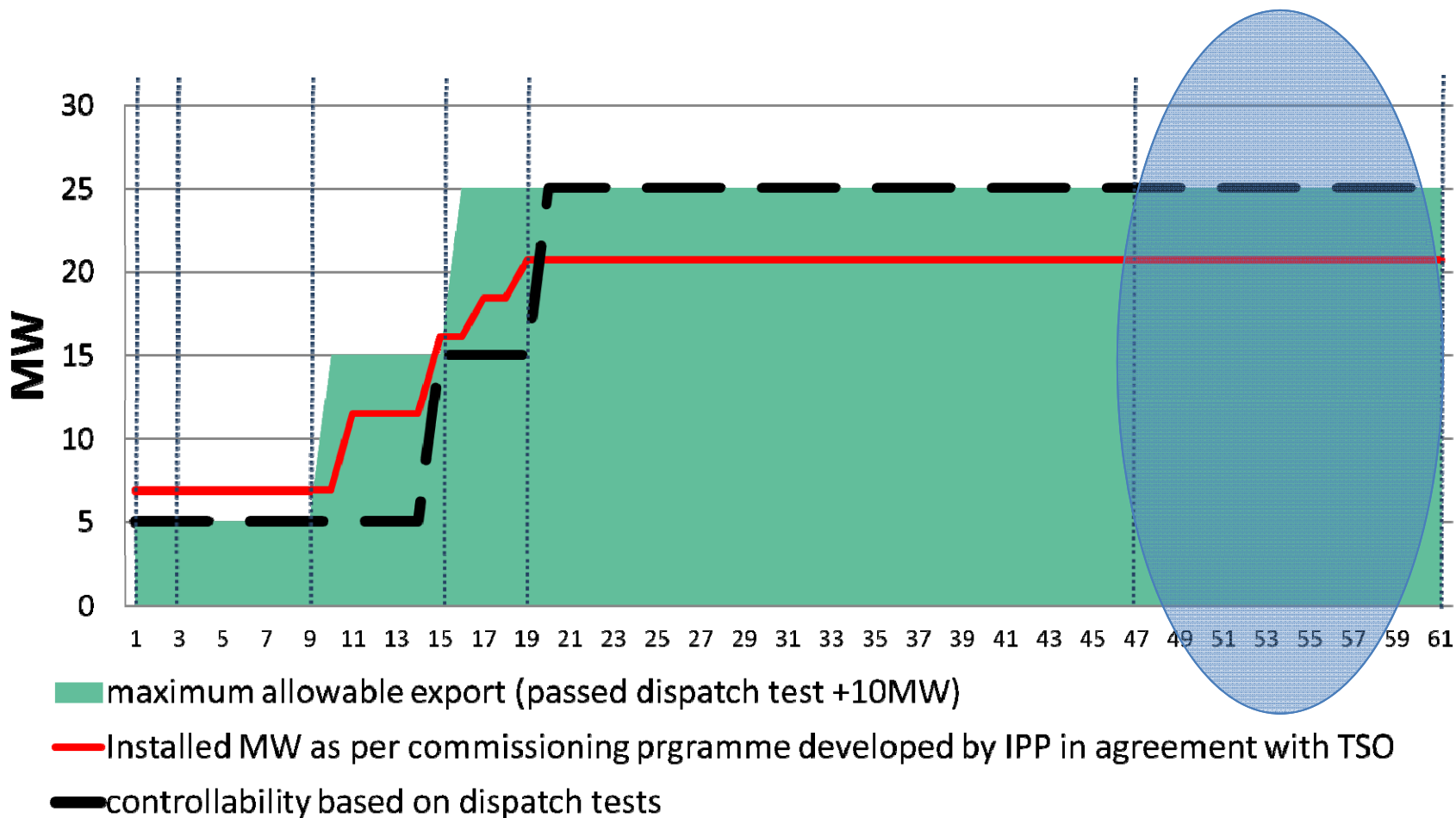
Sample Commissioning Program



- maximum allowable export (passed dispatch test +10MW)
- Installed MW as per commissioning programme developed by IPP in agreement with TSO
- controllability based on dispatch tests



Sample Commissioning Program



Controllability Requirements

Post installation of last turbine

Two key tests

1. The WFPS Active Power Control System is compliant during real time operation and/or during ongoing performance monitoring and testing of the WFPS.
2. The Available Active Power Signal of the WFPS is correct and within the specified quality standard.



Test 1- Active Power Control System

- Turn the active power control on or off through SCADA with acknowledgement from the WFPS;
- Series of MW setpoints issued to the WFPS with acknowledgement from the WFPS;
- WFPS active power control responds within 10 seconds with the required ramp rates to the required dispatch instruction(s);
- Required dispatch instruction set point should be maintained as a maximum until a new set point is issued from the TSO or the active power control is switched off by the TSO.

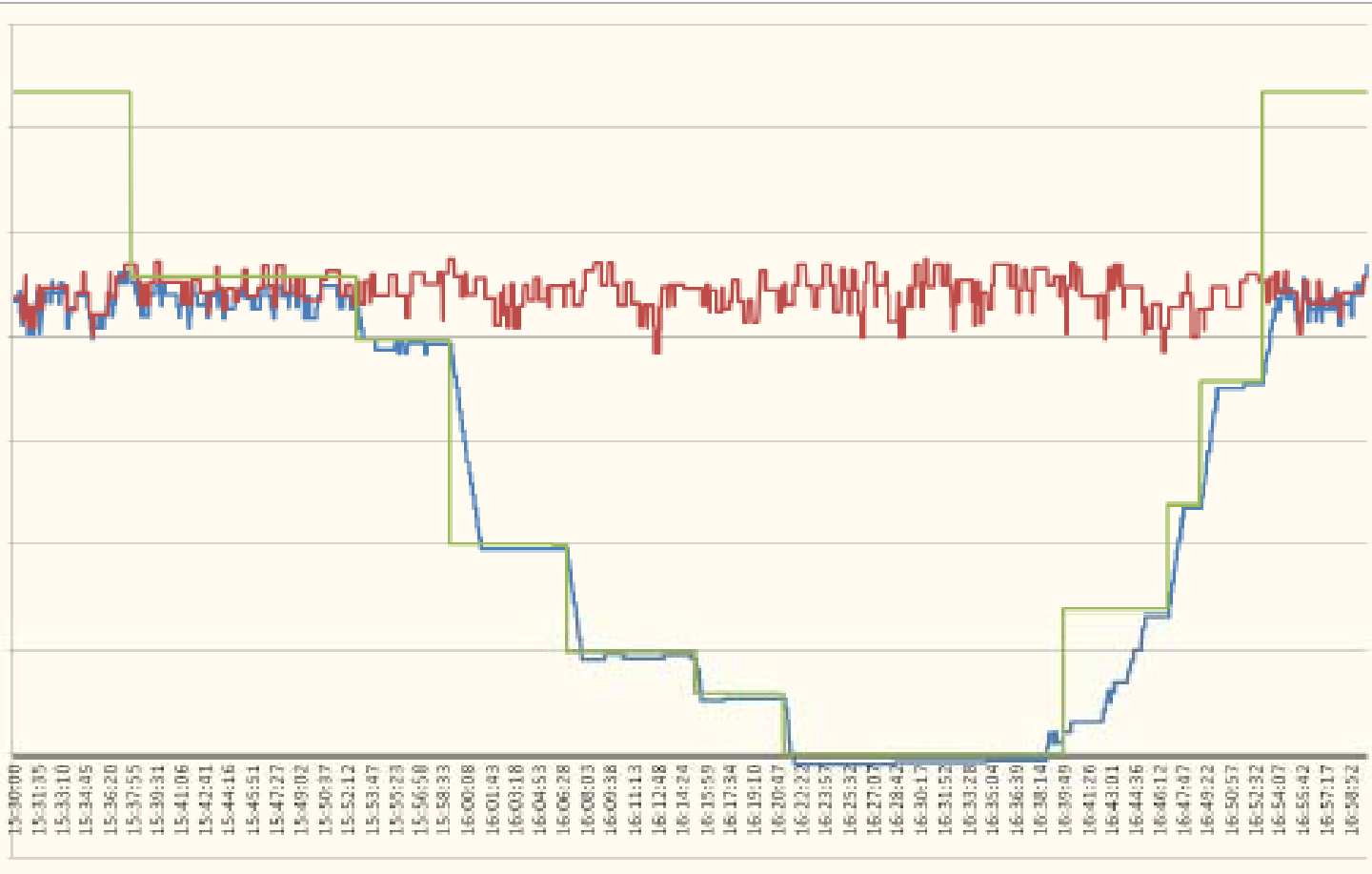


Test 2 - Availability signal is within the TSOs specified quality standard

- This signal at a given time is the measure of the active power a WFPS is capable of delivering to the connection point.
- This signal should account for unavailability of any of the turbines i.e. high and low wind speed shutdown scenarios, outages of a wind turbine generator etc.
- The availability signal of the WFPS is correct and within the specified quality standard.

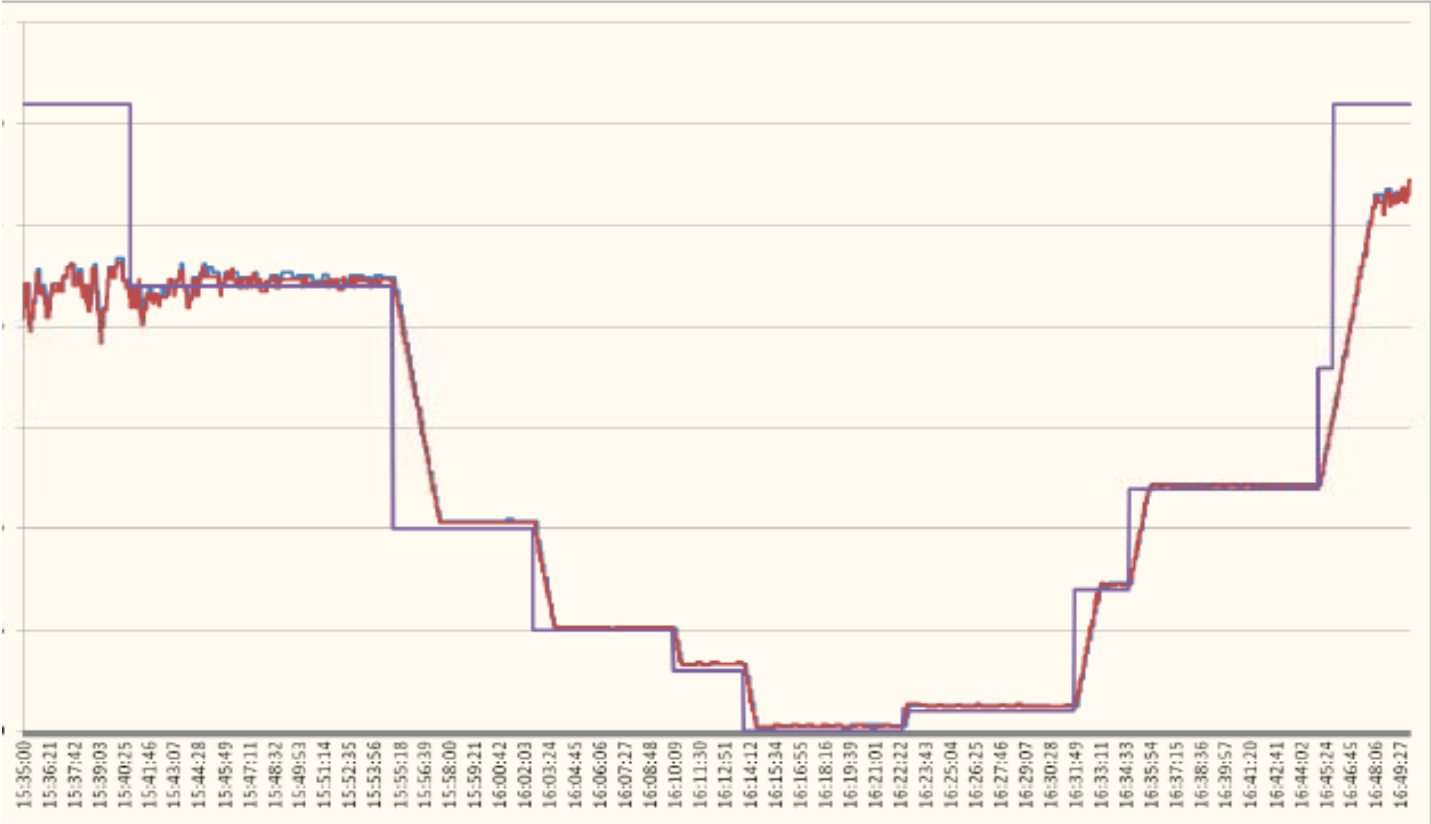


Successful Dispatch Test

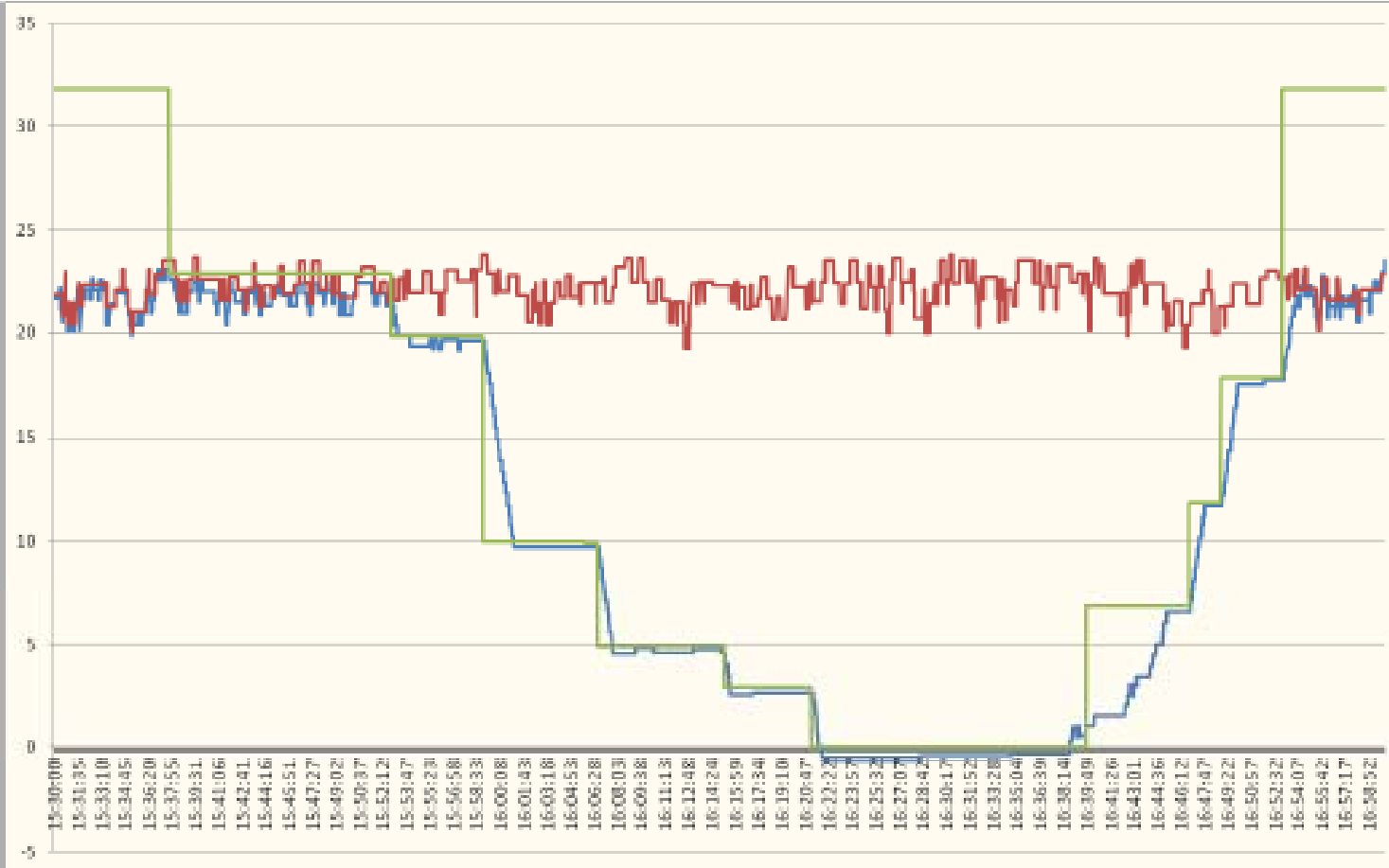


Failed Dispatch Test

Availability Signal is not independent of Active Power Output



Dispatch Test Report



Dispatch Test Report

| Date | Available Active Power | | |
|------------|------------------------|-----------------------|-----------------------|
| | Daily NRMSD | 14-Days Rolling Count | 14-Days Rolling NRMSD |
| 01/09/2012 | 4.74% | 0 | 4.74% |
| 02/09/2012 | 1.32% | 0 | 3.48% |
| 03/09/2012 | 2.85% | 0 | 3.28% |
| 04/09/2012 | 1.97% | 0 | 3.01% |
| 05/09/2012 | 0.91% | 0 | 2.72% |
| 06/09/2012 | 2.14% | 0 | 2.63% |
| 07/09/2012 | 1.44% | 0 | 2.50% |
| 08/09/2012 | 1.88% | 0 | 2.43% |
| 09/09/2012 | 3.87% | 0 | 2.63% |
| 10/09/2012 | 2.81% | 0 | 2.65% |
| 11/09/2012 | 6.04% | 0 | 3.11% |
| 12/09/2012 | 4.01% | 0 | 3.20% |
| 13/09/2012 | 5.24% | 0 | 3.40% |
| 14/09/2012 | 6.14% | 0 | 3.66% |
| 15/09/2012 | 3.14% | 0 | 3.54% |
| 16/09/2012 | 6.25% | 0 | 3.90% |
| 17/09/2012 | 6.80% | 0 | 4.23% |
| 18/09/2012 | 6.29% | 0 | 4.52% |
| 19/09/2012 | 3.06% | 0 | 4.59% |
| 20/09/2012 | 4.09% | 0 | 4.68% |
| 21/09/2012 | 1.93% | 0 | 4.69% |
| 22/09/2012 | 2.22% | 0 | 4.71% |
| 23/09/2012 | 2.93% | 0 | 4.66% |
| 24/09/2012 | 0.99% | 0 | 4.60% |
| 25/09/2012 | 4.86% | 0 | 4.50% |
| 26/09/2012 | 4.28% | 0 | 4.52% |
| 27/09/2012 | 3.38% | 0 | 4.39% |
| 28/09/2012 | 6.05% | 0 | 4.38% |
| 29/09/2012 | 6.30% | 0 | 4.62% |
| 30/09/2012 | 6.46% | 0 | 4.63% |



Dispatch Test Report

| | | | |
|--|---------------|----------------------|----------------------|
| Active Power Control System | PASS | | |
| Available Active Power System | PASS | | |
| Available Active Power Signal for period 01/11/2011 to 12/01/2012. | Overall NRMSD | 14 Day Rolling Count | 14 Day Rolling NRMSD |
| | 1.53 % | 0 days | 0 days |



Dispatch Test Report

Successful dispatch test

- PASS means 10 MW increase in Export Limit
- PASS means Operational Readiness Confirmation
 - » If Operational Readiness is achieved, the unit may now register as VPTG in the market
 - » Units >10MW are required to register as a VPTG in the SEM



Category (iii) Commissioning

- Operational Readiness deadline: 6 weeks from installation of last turbine
- This group of WFPS will be dispatched in the event that re-dispatch of Category (i) and Category (ii) WFPS is not sufficient.
- Currently 16 WFPS in this category (RoI)



Category (iii) Commissioning

| Wind Farms Connected in Ireland | | | |
|---------------------------------|--------------------------|-----------------------|---|
| Wind Farm Name | Associated 110kV Station | Installed Capacity MW | Hierarchy |
| Altagowlan | Corderry | 7.65 | (iii) Controllability Works Outstanding |
| Black Banks 2 | Corderry | 6.8 | (iii) Controllability Works Outstanding |
| Boggeragh | Boggeragh | 57 | (iii) Controllability Works Outstanding |
| Carraigcannon | Boggeragh | 23 | (iii) Controllability Works Outstanding |
| Carrowleagh | Glenree | 36.8 | (iii) Commissioning |
| Coomatallin | Dunmanway | 6 | (iii) Controllability Works Outstanding |
| Corkermore | Binbane | 10 | (iii) Controllability Works Outstanding |
| Cronelea 1 | Carlow | 6.9 | (iii) Controllability Works Outstanding |
| Cronelea 2 | Carlow | 6.9 | (iii) Controllability Works Outstanding |
| Dromada | Dromada | 28.5 | (iii) Controllability Works Outstanding |
| Gneeves | Knockeragh | 9.35 | (iii) Controllability Works Outstanding |
| Kealkil | Ballylickey | 8.5 | (iii) Controllability Works Outstanding |
| Lackan | Moy | 6.9 | (iii) Controllability Works Outstanding |
| Mountain Lodge | Ratrussan | 31.5 | (iii) Controllability Works Outstanding |
| Mullananalt | Meath Hill | 7.5 | (iii) Controllability Works Outstanding |
| Taurbeg | Glenlara | 25.3 | (iii) Controllability Works Outstanding |
| Total Hierarchy (iii) | | 278.6 | |



Moving From Category (iii) to Category (ii)

- Once Operational Readiness Confirmation is received.



Category (ii) - Controllable

- This group of WFPS will be dispatched in the event that re-dispatch of Category (i) WFPS is not sufficient.
- There are 40 WFPS in this Category (RoI)



Category (ii) - Controllable

| Wind Farms Connected in Ireland | | | |
|---------------------------------|--------------------------|-----------------------|-----------|
| Wind Farm Name | Associated 110kV Station | Installed Capacity MW | Hierarchy |
| Ballincollig Hill | Tralee | 13.3 | (ii) |
| Ballybane 1 & 2 | Ballylickey | 29.9 | (ii) |
| Ballymartin | Waterford | 6 | (ii) |
| Ballywater | Crane | 42 | (ii) |
| Bawnmore | Macroom | 25.3 | (ii) |
| Beam Hill | Trillick | 14 | (ii) |
| Bindoo | Ratrussan | 48 | (ii) |
| Booltiagh | Booltiagh | 19.5 | (ii) |
| Caherdowney | Garrow | 9.2 | (ii) |
| Castledockrell | Castledockrell | 41.4 | (ii) |
| Clahane | Clahane | 40 | (ii) |
| Coomacheo | Garrow | 59.8 | (ii) |
| Coomagearlahy 1 (Kilgarvan) | Coomagearlahy | 45 | (ii) |
| Coomagearlahy 2 (Sillahertane) | Coomagearlahy | 8.5 | (ii) |
| Coomagearlahy 3 (Inchincoosh) | Coomagearlahy | 32.5 | (ii) |
| Derrybrien | Agannygal | 59.5 | (ii) |
| Dromdeeven | Glenlara | 28 | (ii) |
| Drumlough Hill 2 | Trillick | 10.2 | (ii) |
| Flughland | Some Hill | 9.2 | (ii) |
| Garvagh 1 (Glebe) | Garvagh | 26 | (ii) |
| Garvagh 2 (Tullynahaw) | Garvagh | 22 | (ii) |
| Glanlee (Midas Gen unit) | Glanlee | 32.45 | (ii) |
| Glenough | Cauteen | 32.5 | (ii) |
| Gortahile | Carlow | 20 | (ii) |
| Grouse Lodge | Rathkeale | 15 | (ii) |
| Kingsmountain 2 (Dunneil) | Cunghill | 11.05 | (ii) |
| Knockastanna | Ardnacrusha | 6 | (ii) |
| Knockawarriga | Trien | 22.5 | (ii) |
| Lisheen | Lisheen | 36 | (ii) |
| Loughderryduff | Binbane | 7.65 | (ii) |
| Meenachullalan | Binbane | 13.8 | (ii) |
| Meentycat | Drumkeen | 86.4 | (ii) |
| Muingnaminanne | Tralee | 14.8 | (ii) |
| Raheen Bar 2 (Derrynadivva) | Castlebar | 8 | (ii) |
| Rathcahill | Rathkeale | 12.5 | (ii) |
| Richfield | Wexford | 27 | (ii) |
| Some Hill 1 & 2 | Some Hill | 38.9 | (ii) |
| Tournafulla 1 | Trien | 7.5 | (ii) |
| Tournafulla 2 | Trien | 18 | (ii) |
| Tullynamoyle | Cordery | 9.2 | (ii) |
| Total Hierarchy (ii) | | 1008.55 | |



Category (ii) - Controllable

- WFPS in this category have 12 months from date of Operational Readiness Confirmation to complete full Grid Code Testing and achieve an Operational Certificate



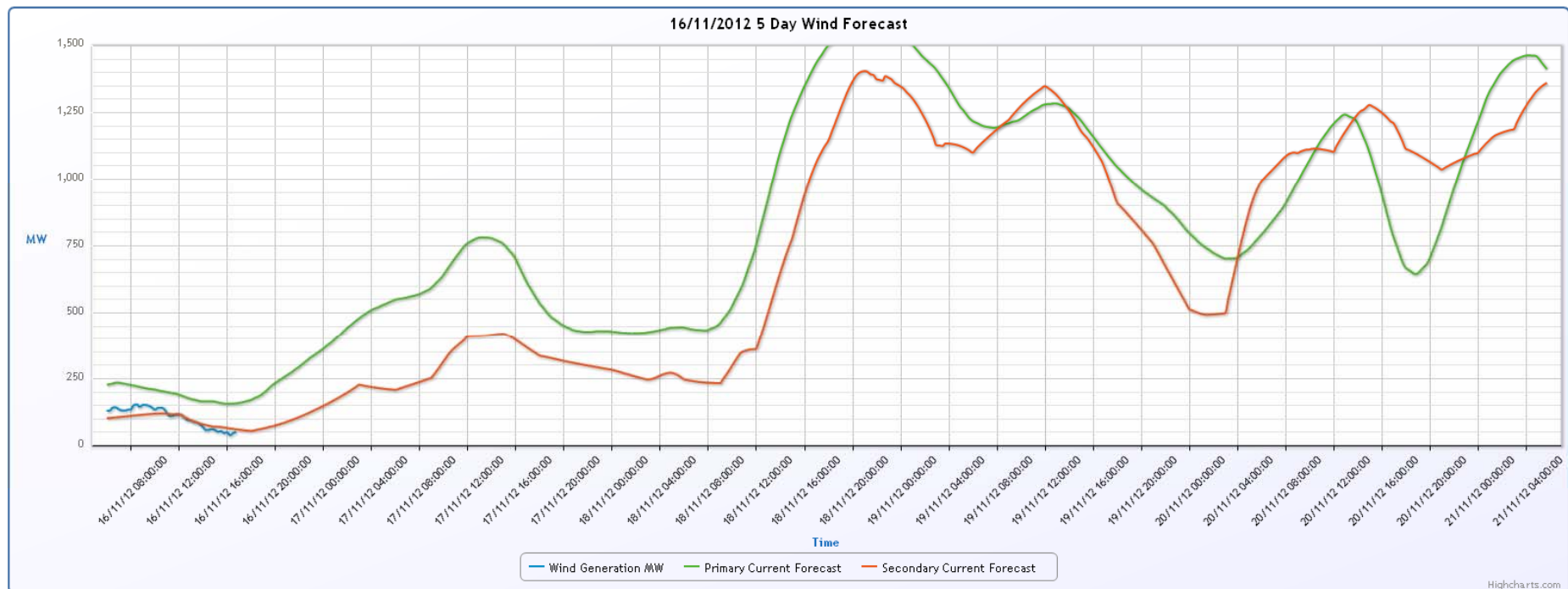
Scheduling GCCT

- Calendar system
- One unit per test day
 - Mon – Fri (9am – 5pm)
- GCCT testing approx 1.5 days



Wind Forecasting

Forecasting Tool by EirGrid



Wind Forecasting

- Forecast 5/3/1 days in advance
- Confirmation 1 day in advance



Grid Code Testing

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November 19th 2012



Grid Code Testing

1. Active Power Control
2. Frequency Response
3. Ramp Rate and Start up Test
4. Automatic Voltage Regulation
5. Reactive Power Capability
6. Capacity Test
7. Black Start Shutdown Test



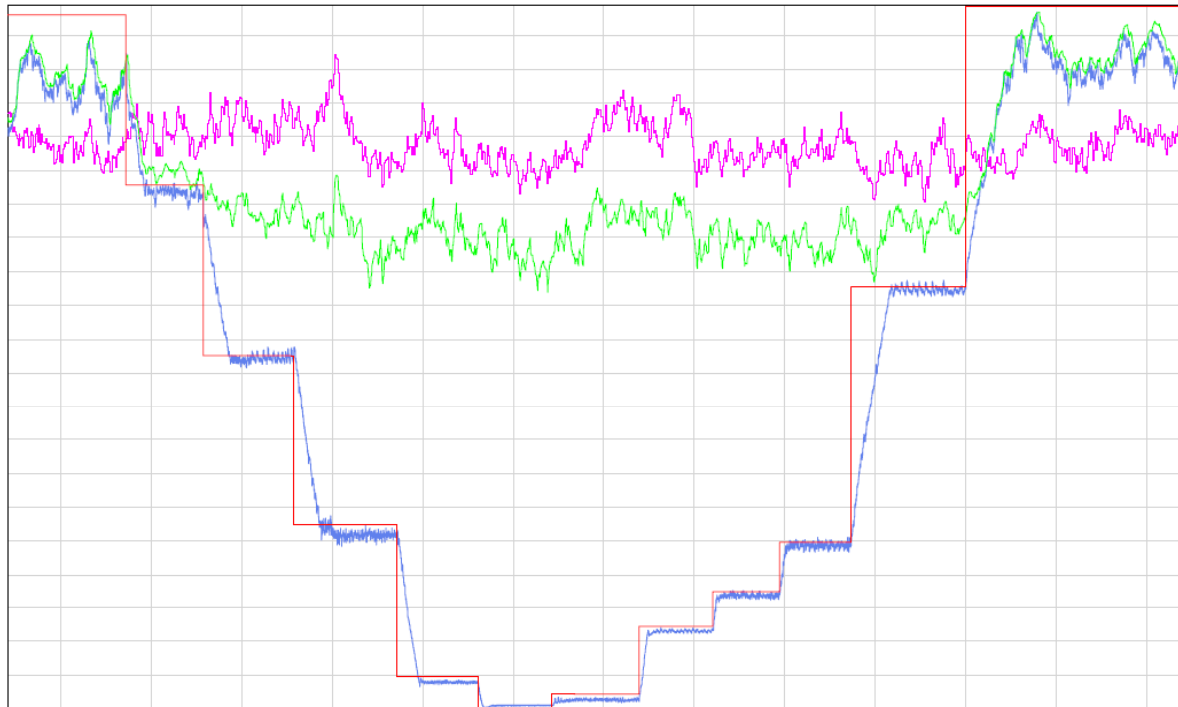
Active Power Control

| Grid Code Clause (V3.4) | Description | Pass Criteria |
|-------------------------|---|--|
| WFPS 1.5.2.1 | Ability to respond to active power setpoints | Average value of power to be within $\pm 2.5\%$ of set-point value, averaged over the length of time from when the unit should have implemented the setpoint to when the setpoint was changed; or over 10 minutes, whichever is less |
| WFPS 1.5.2.1 | Implementation of active power setpoint on receipt of signal from NCC | Response required in 10 s or less |
| WFPS 1.5.2.1 | Rate of change of power should be bound by the maximum ramp rate settings advised by TSO. (Refer to WFPS1.5.3). | Rate of change of active power no less than the 1 min and 10 min averaged ramp rates as defined by the TSO. |



Active Power Control

Series of active power setpoints issued



Ramp Rate and Start up Test

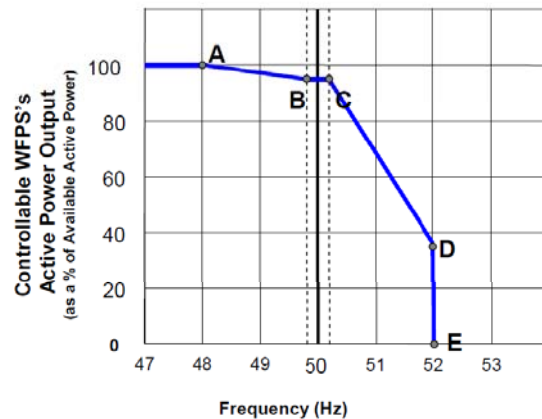
- Tested with the Active Power Control system and by local stop/start

| Grid Code Clause (V3.4) | Purpose of Test and Description | Pass Criteria |
|-------------------------|--|--|
| WFPS 1.5.3 | Confirm the ability of the wind farm to start-up and ramp up to available wind capacity and ramp down ** | The rate of change of active power no greater than the 1 min and 10 min averaged ramp rates as defined by the TSO. |



Frequency Response

- Curve 1 and Curve 2
- Tested with Active Power Control On and OFF

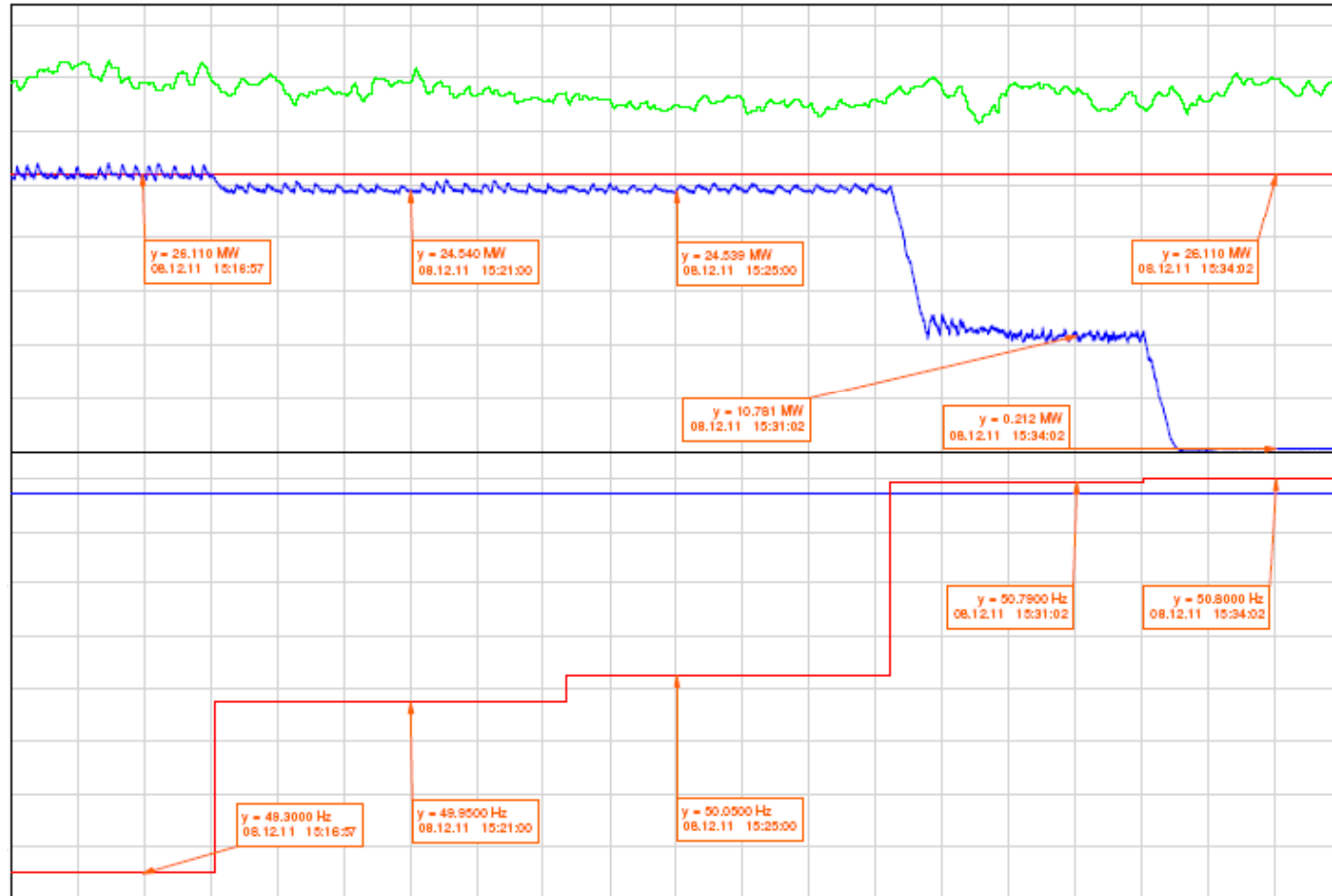


| | Frequency (Hz) | Available Active Power (%) | Frequency (Hz) | Available Active Power (%) |
|---|----------------|----------------------------|----------------|----------------------------|
| | Curve 1 | | Curve 2 | |
| A | 47 | 100 | 49.3 | 100 |
| B | 49.8 | 100 | 49.95 | 95 |
| C | 50.2 | 100 | 50.05 | 95 |
| D | 50.79 | 76.67 | 50.79 | 44 |
| E | 50.80 | 0 | 50.80 | 0 |

| Grid Code Clause (V3.4) | Purpose of Test and Description | Pass Criteria |
|-------------------------|--|--|
| WSPS 1.5.2.2 | Confirm that settings for Curve 1 are implemented. | Curve 1 implementation required within 1 minute of receiving signal from NCC |
| WSPS 1.5.2.2 | Frequency Response to Curve 1 with Active Power Control 'Off'. | Rate of response required minimum 1% of rated capacity per second. |
| WSPS 1.5.2.2 | Frequency Response to Curve 1 with Active Power Control 'On'. | Rate of response required minimum 1% of rated capacity per second. |
| WSPS 1.5.2.2 | Confirm that settings for Curve 2 are implemented. | Curve 2 implementation required within 1 minute of receiving signal from NCC |
| WSPS 1.5.2.2 | Frequency Response to Curve 2 with Active Power Control 'Off'. | Rate of response required minimum 1% of rated capacity per second. |
| WSPS 1.5.2.2 | Frequency Response to Curve 2 with Active Power Control 'On'. | Rate of response required minimum 1% of rated capacity per second. |



Frequency Response

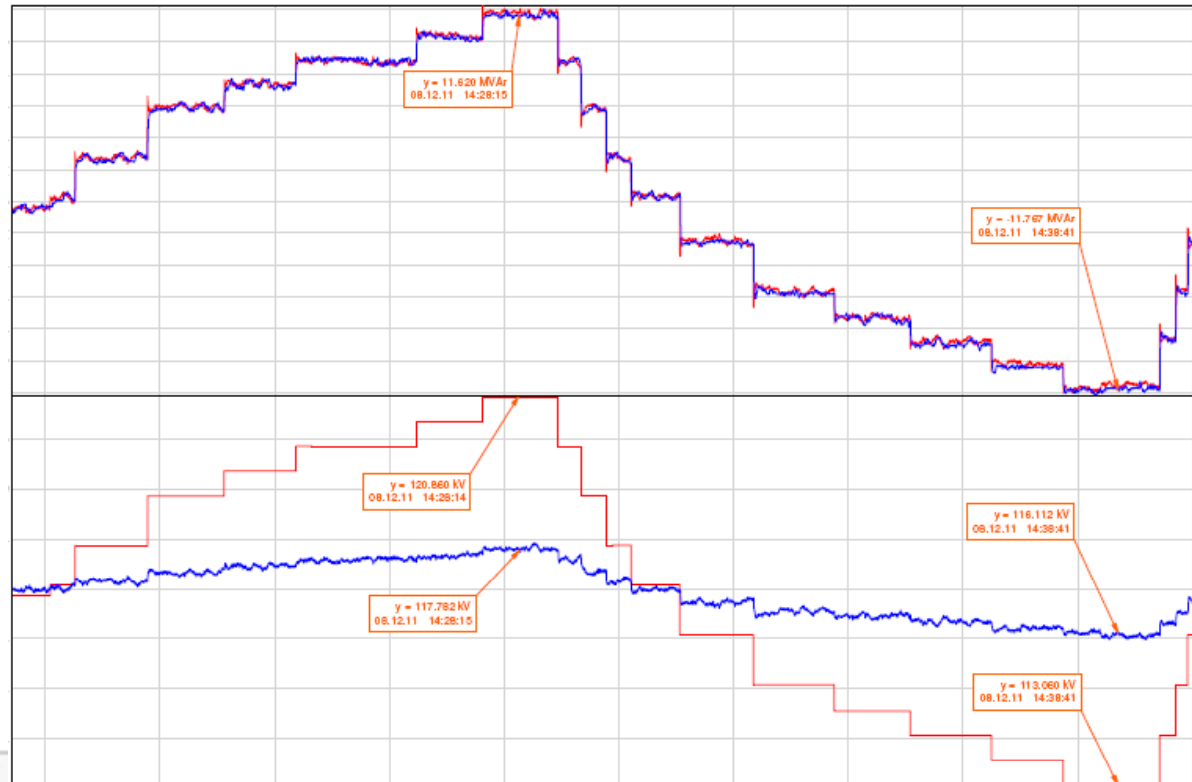


Automatic Voltage Control

| Grid Code Clause (V3.4) | Description | Pass Criteria |
|-------------------------|--|---|
| WFPS 1.6.2 | Confirm the ability of wind farm to respond to dispatch voltage set-points from NCC. | Voltage regulation for given droop setting to be within limits set out in contractor's voltage study that will have been approved by Eirgrid. |
| | Confirm that actual voltage slope settings concur with selected voltage slope settings of 1% and 4%. | Actual voltage slope per applied voltage slope setting. |
| | Confirm that change in voltage regulation set-point is implemented by the wind farm within 20 seconds of receipt of the signal from NCC. | Response implemented within 20 seconds or less |
| | Confirm that 90% of the steady state reactive power response occurs within 1 second. | Response of 90% of steady state reactive power required within 1 second |



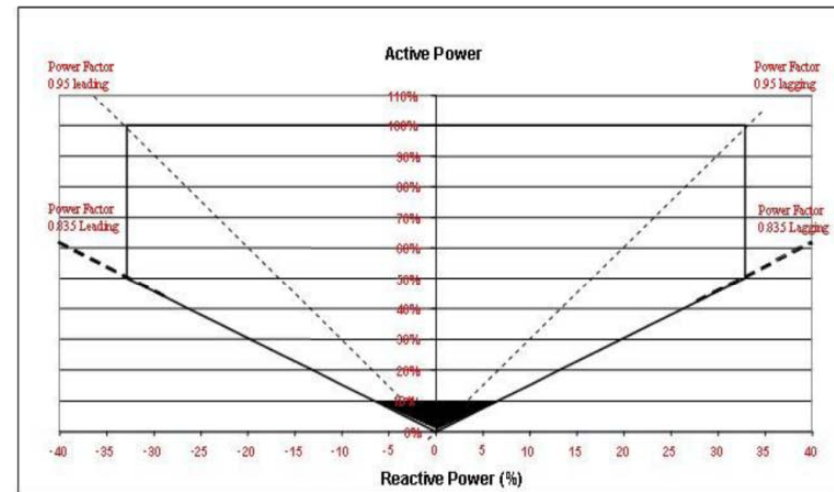
Automatic Voltage Regulation



Reactive Power Capability

The wind farm shall clearly demonstrate that the reactive power capability for both export of reactive power and import of reactive power at wind farm voltage at Point Y, (normally medium voltage), can operate within and up to the limits of the reactive power characteristic as set out in Figure WFPS1.4 of the Grid Code.

| Grid Code Clause (V3.4) | Purpose of Test and Description | Pass Criteria |
|-------------------------|---|-----------------|
| WFPS 1.6.3 | Confirm the ability of wind farm to provide reactive power over the full range of the capability diagram Figure WFPS1.4 of the Grid Code. | Detailed above. |



Black Start Shutdown Test

- Operation of Blackstart Shutdown system from NCC
- Confirmation of correct operation of switchgear, interlocking and signalling



Capacity Test

On completion of the tests, the results should demonstrate:

- Where wind conditions are in excess of 90% of the capacity of the wind farm, confirm as far as is practicable, that the wind farm can produce output towards its registered maximum export capacity (MEC), and at rated lagging reactive power (export) for a period of at least one hour without distress to the equipment, such distress being identified by the occurrence of an alarm or a shutdown condition on any wind turbine.

| Purpose of Test and Description | Instrumentation & Information Output | Instrumentation Accuracy and Information Output Accuracy | Pass Criteria |
|--|--|---|------------------------------|
| Confirm that the wind farm can provide its registered maximum export capacity (MEC) at rated reactive power (lagging) for a period of no less than one hour. | Data recording of the following: <ul style="list-style-type: none"> • Available active power • Active power at grid voltage • Energy at grid voltage • Reactive power at wind farm voltage | <ul style="list-style-type: none"> • Use of installed permanent metering for active power. • Limits of overall accuracy in measurement and resolution $\pm 1.0\%$, time resolution 1 second. | No alarms or trip conditions |



Comments and Feedback welcome

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