NGED Active Network Management Guidance

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1. Introduction

National Grid Electricity Distribution (NGED) are using Active Network Management (ANM) to enable connections across its network. This document provides the technical detail and requirements that connections must follow to utilise ANM. Customers must adhere to all other NGED policies with regard to a connection to the network.

The information in this document is to enable customers to design their connections to meet NGED's requirements ahead of an application and commissioning. The ANM system can be used to instruct real or reactive power, import or export constraints. This allows the control of both demand and generation connections, for demand or reverse power flow constraints. Connections at 11kV and above can be controlled by the ANM system to manage constraints from primary transformers up to the transmission network interface.

2. Definitions

Active Network Management (ANM):

NGED's control system to manage Connections at 11kV, 33kV, 66kV & 132kV against constraints on the Distribution network, Super Grid Transformers (which act as the distribution to transmission interface), and Transmission network. Where contractual distinction is required these are referred to as DANM, SGT ANM (formerly TANM), and Technical Limits ANM but are handled by the same system.

Connection Control Panel (CCP):

The grid edge device used as the interface between NGED and the customer. It provides 4-20mA control signals and ensures compliance of the import/export of the site by escalation.

Connection:

NGED's ANM system can manage both generators or demand connections. The import or export of a site can be controlled by the same mechanism and infrastructure.

ICCP:

Inter-Control Center Protocol. IEC standard which defines the process for sending data between control systems. The data that can be sent is defined such that only the intended data type can be transferred.

Last In First Out (LIFO):

The methodology used to determine the priority order of curtailment of connections by the ANM system.

Pre-event Limit:

The value against which curtailment is calculated, based on the load after an arranged outage or fault. This is used rather than the asset rating to ensure short term post outage/fault overloads do not occur.

Sensitivity Factor:

The contribution of a connection to a constraint.

Set Point:

The required maximum/minimum import/export that the ANM system allows the connection to operate at. This is communicated as a mA value, which corresponds to a MW or MVAr value.

Supervisory Control and Data Acquisition (SCADA):

NGED's communication and control process between the PowerOn Advanced Distribution Management System and the network. All monitoring data is transferred using this communication network.

3. ANM Curtailment Concept

The simplest ANM scenario would involve a new generator connection needing to be curtailed at maximum operation, when the demand was at its minimum, to avoid overloading the circuit supplying the substation.

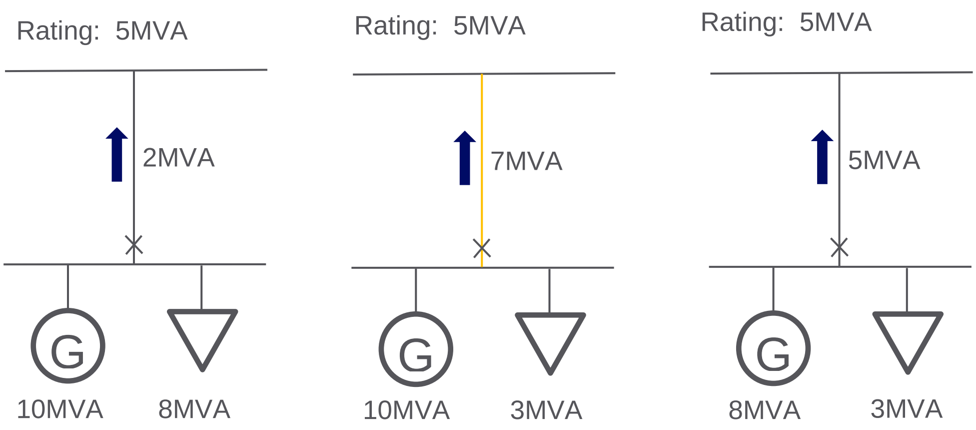


Figure 1: Basic ANM Condition

In the example shown in Figure 1, initially when the generator is exporting 10MVA, the local demand imports 8MVA, 2MVA flows on the 5MVA rated circuit. But when the local demand drops to 3MVA, the circuit is overloaded to 7MVA. In this scenario the ANM system would curtail the output of the generator to 8MVA to remove the overload.

In a more complex example multiple constraints and multiple generators need to be handled by the ANM system. This can lead to imbalanced loading on constraints and the introduction of a Last In First Off (LIFO) stack to determine the order of which generators are curtailed.

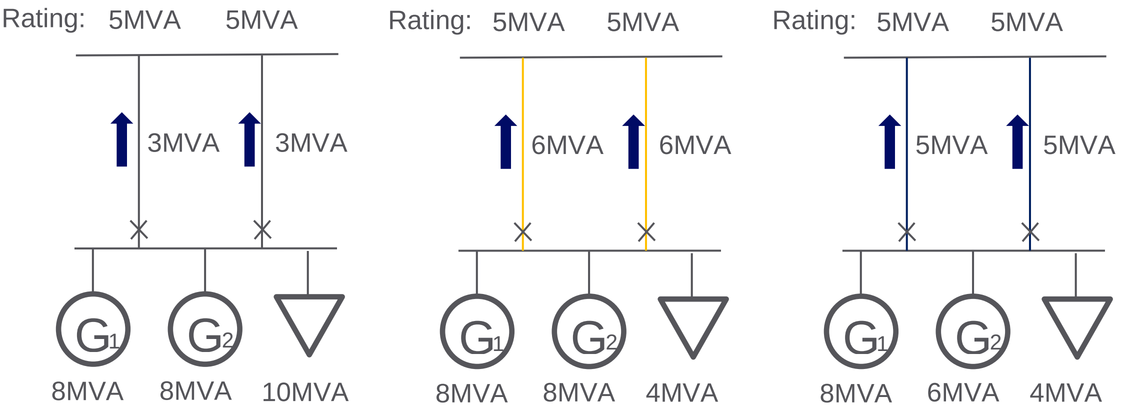


Figure 2: LIFO Stack ANM Condition

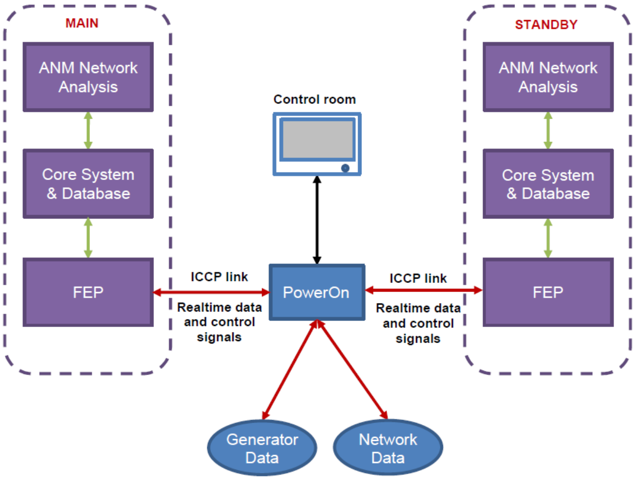
In the example shown in Figure 2, initially when both generators are exporting 8MVA, the local demand imports 10MVA, 3MVA flows on the 5MVA rated circuits. But when the local demand drops to 4MVA, the circuits are overloaded to 6MVA. In this scenario where G_1 was the first to apply and G_2 came afterwards, the ANM system would allow G_1 to continue at 8MVA and curtail G_2 to 6MVA. This brings the load on the circuits back to 5MVA.

NGED calculate the required curtailment based on a pre-event limit, rather than the asset rating, to avoid short term post outage/fault overloads. Section 5.d provides a full description of this approach.

4. ANM System Architecture

NGED's ANM systems operate by monitoring the live network using a centralised control system, which calculates the required set points for each ANM connection to ensure the network does not overload. These are sent to each connection using NGED's existing communication network and instructed to the customer using a CCP. NGED uses two suppliers for its ANM systems but they use the same system architecture. An ANM zone is implemented per Grid Supply Point (GSP) or GSP group.

The diagram below represents the architecture and shows the redundant capability of the system.



a. Centralised ANM System

An ICCP link connects NGED's PowerOn Distribution Management System, which monitors the network status and loading in real time, to a server-based ANM environment. Within this environment the software which handles the network data and calculates the set points is run with a fully dual-redundant capability, to ensure system availability.

b. Communication Network

NGED's SCADA network communicates the status of the circuit breakers and isolators across the network and allows their control in real time. It also records the Amp, Volt, MW & MVAr loading at all available points. This data is fed into the ANM system for every required point within an ANM zone.

The set point calculated by the ANM system is sent to the customer using the existing communications network to a NGED RTU at the connection's substation.

All sites connecting to NGED's ANM system must meet NGED's Standard Technique: SD1G/2. This includes the use of one of the following depending on connection capacity:

i. Microwave
ii. Fibre Optic
iii. UHF Licences Radio

If the communication connection from the customer's site back to NGED's Distribution Management System (PowerOn) is lost the CCP will enter a pre-defined known state. After a defined delay period Stage 1 will be applied (see 5.b for details). When the connection is re-established Stage 1 will automatically be released.

c. Connection Control Panels

All sites connecting using ANM must have a CCP. This is the device that NGED's RTU communicates with to send the required set point, monitor the operation of the connection and instigate measures in the case of non-compliance to requirements. Where ANM is required for an extension multiple CCPs may be required.

The output for this device is presented to the customer via a Customer Interface Panel to provide a boundary of responsibility. An example of the wiring for a 33kV connection can be found below. Please contact NGED for the relevant diagram for each connection voltage.

33CCP-SCHEME_Rev 8.pdf

Further documentation on CCPs & connection guidance can be found NGED's website: https://www.nationalgrid.co.uk/documents/tech-info

5. Operational Conditions

Connections must follow the set point that is sent to them and the adherence of this is policed locally by the CCP. This is achieved by escalating the operation of the connection in 3 stages as detailed below:

a. Stage 0

This is the state for normal automated operation, in which the customer is presented with a 4-20mA, 12-bit integer signal, which equates to the MW or MVAr value the customer must not exceed. This signal can be sent over 4 channels to give control for:

1. Real Power Lower Bound (export)
2. Real Power Upper Bound (import)
3. Reactive Power Lower Bound (export)
4. Reactive Power Upper bound (import)

The 4-20mA signals are used to create bounds of operation, where by the site must operate above or below the applied set point. Across this 4-20mA range 12mA is used to represent 0MW, 20mA representing full scale +ve (import), and 4mA representing full scale –ve (export). On the mA scale the output of the connection must always be greater than the lower bound set point and less than the upper bound set point. Customer equipment must therefore be capable of measuring and resolving the analogue mA signal accordingly. If an error occurs on this connection 0mA will be presented to the customer, upon which it is expected that the site will constrain to 0MW until the issue is resolved.
The definition of "Full Scale" will be determined by a size category dependent on the greater of the customer's maximum import or export capacity as follows (whichever is greatest):

- Up to and including 5MW:
  Full Scale is +/- 5MW (Real) and +/- 5MVar (Reactive)
- Up to and including 20MW but greater than 5MW:
  Full Scale is +/- 20MW (Real) and +/- 20MVar (Reactive)
- Up to and including 100MW but greater than 20MW:
  Full Scale is +/- 100MW (Real) and +/- 100MVar (Reactive)

If required additional templates will be created for larger sites.

The formula to convert the mA (I) signal to kW (P) is:

$$P_{Set\ Point} = \left(\left(\frac{I - I_{Min\ I}}{I_{Range}}\right) \times P_{Range}\right) - P_{Min\ P}$$

I: mA value received from the analogue module

$I_{Min\ I}$: the low mA range value of 4

I_{Range}: the mA range e.g. 4 – 20 = 16

P_{Range}: "Full Scale" as detailed above e.g. for +/- 20 MW = 40

$P_{Min\ P}$: The lowest of the “Full Scale” range e.g. for +/- 5MW = 5

For each of the 3 “Full scale” templates the formula can be simplified to:

- 5MW:

$$P_{Set\ Point} = \left(\left(\frac{I-4}{16}\right) \times 10\right) - 5$$

- 20MW:

$$P_{Set\ Point} = \left(\left(\frac{I-4}{16}\right) \times 40\right) - 20$$

- 100MW:

$$P_{Set\ Point} = \left(\left(\frac{I-4}{16}\right) \times 200\right) - 100$$

These settings are demonstrated in Figure 3, where the requirement of a 4MW import/export site to operate greater than 3MW for the export and less than 2MW for the import. NB NGED use a convention of positive to represent import (demand) and negative to represent export (generation) relative to the connected site.

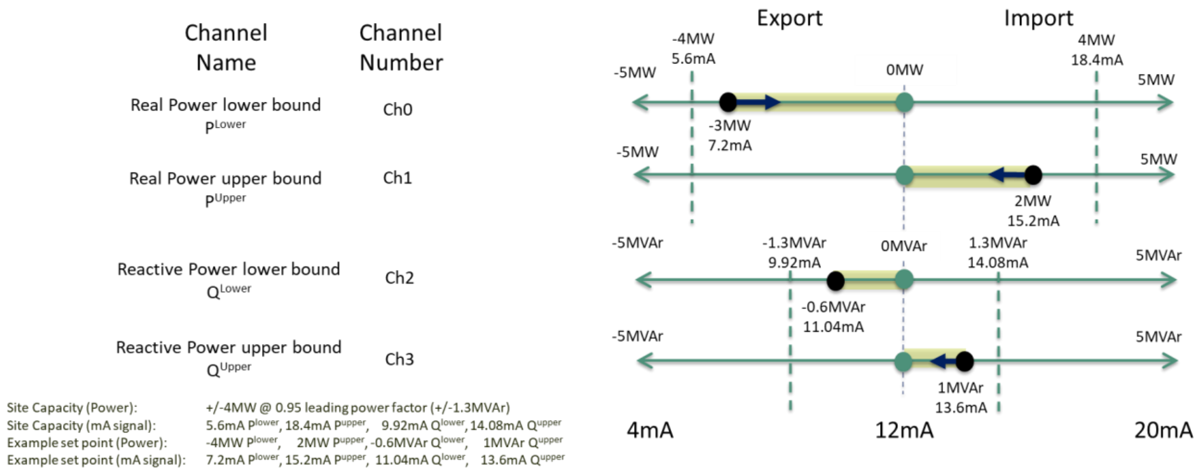


Figure 3: CCP settings example

On issuing of a set point to the customer via the CCP the import/export of the connection must meet the new required value within a set period of time. The default requirement is 10 seconds. Therefore on applications customer must inform NGED of the ramp rate capability of the connection. If these times are not aligned the CCP will escalate to Stage 1 (as detailed below) on a regular basis.

A small dead band of between 100 & 1000kW is applied to the Set Point to account for any noise within the signal communicated to the customer to avoid spurious curtailment.

b. Stage 1

Stage 1 is initiated by escalation from Stage 0 if the import/export of the site is not reduced within the required time. But it can also be triggered by a loss of communications to the site, manually on-site/from NGED’s control room or automatically by a wide area control system such National Grid Electricity System Operator’s (NG ESO) Connect and Manage.

A digital enable signal will be provided to trigger Stage 1 and a confirmation signal must be returned by the customer’s control system (see CCP schematic for wiring arrangement). The connection’s import/export must be reduced to a predefined value (the default is 0MW) when this signal is enabled, within a predetermined time frame or usually 10 seconds.

Once the trigger for Stage 1 is removed, the CCP will automatically revert to Stage 0. Therefore if the site was too slow to adhere to the Stage 0 set point and escalated to Stage 1, once the import/export reaches 0MW the CCP will revert to the Stage 0 set point. Errors in configuration can leading to a “hunting” scenario, where the CCP and connection are chasing a stable point.

During commissioning this will be tested by sending a signal on site and from NGED’s Control Centre to verify the import/export goes to the predefined value. The signal will be reset, removing the enable signal, and it would be expected that the site would start to export again.

c. Stage 2

Stage 2 is initiated by escalation from Stage 1 if the import/export of the site is not reduced within the required time. But it can also be triggered manually on-site/from NGED’s Control Centre or automatically by a wide area control system such NESO’s N-3 operational intertrip scheme.

A digital enable signal will be provided to trigger Stage 2 and a confirmation signal must be returned by the customer’s control system (see CCP schematic for wiring arrangement). The customer-owned breaker associated with the controllable load must be hardwired to open upon enabling of this signal. Where ANM is applicable to embedded connections, the breaker associated with the controllable load must be opened but the rest of the existing site can remain energised.

Stage 2 can only be removed by NGED’s Control Centre or manually on site.

In the event of a failure of the communications network (Comms fail) to the CCP a Stage 1 signal is applied after a site specific defined time delay. If the Stage 1 requirement is not adhere to the site will automatically escalate to Stage 2. Upon restoration of communications, if the site is in Stage 1 it will automatically reset, however, if it has escalated to Stage 2 NGED’s Control Centre will have to manually reset it.

During commissioning this will be tested on site and from NGED’s Control Centre to verify the circuit breaker opens and the site is no longer exporting. The signal will be reset, removing the enable signal, and it would be expected that the site would start to export again.

An overview of this escalation process is shown below in Figure 4.

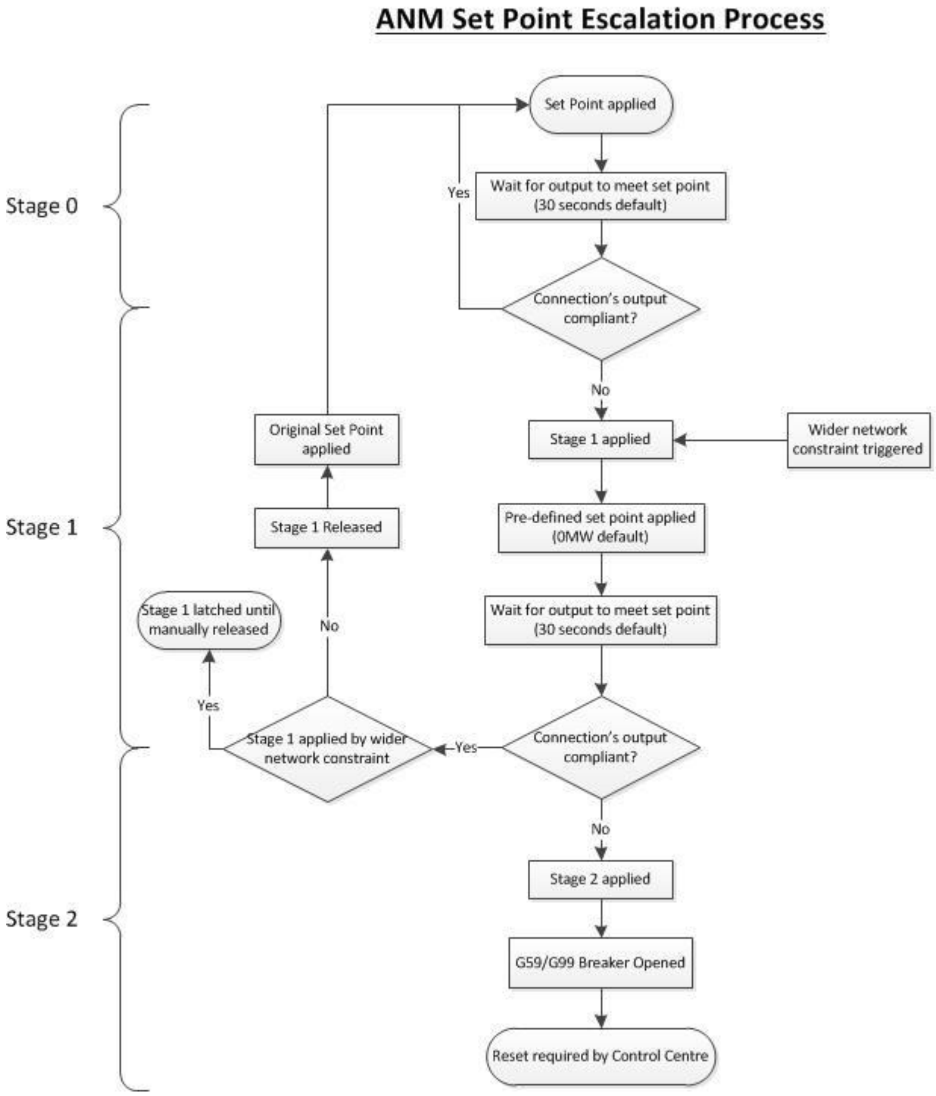


Figure 4: CCP Escalation Process

d. Constraint requirements

The ANM system is constantly monitoring the loading on network and pre-identified constraints. If the load or voltage on these constraints goes over the defined limit the ANM system will calculate the required set point for each connection that contributes to the constraint. Within an ANM zone only those connections with a sensitivity factor above a fixed threshold will be constrained. Therefore a connection will only be constrained if this will help to alleviate a constraint.

NGED employs a pre-event limit approach to operating its ANM system. This means that rather than curtailing against the full rating of an asset, a limit is calculated based on the maximum change in load or voltage following an event. This could be a change in topology or rapid change in load (e.g. loss of demand or sudden export of generation). An example of this is shown below:

Pre-event Limit Example

1. Initially each circuit is limited to 8MVA, despite being rated up to 12MVA	2. When a fault or outage is taken the other two circuits will share the 8MVA, which flowed through the now out of service circuit. By limiting the original load to 8MVA an instantaneous overload is avoided
3. For a prolonged outage this full loading could be maintained to fully utilise the network capability	4. However, for a subsequent fault the remaining circuit would be loaded to 24MVA, 200% of its rating. If the ANM system is not able to curtail generation within a short period of time this will damage the network
5. A second pre-event load limit of 6MVA can be applied to mitigate against an overload	6. When a further fault occurs the remaining circuit is only loaded up to its rating of 12MVA, avoiding any damage to the network

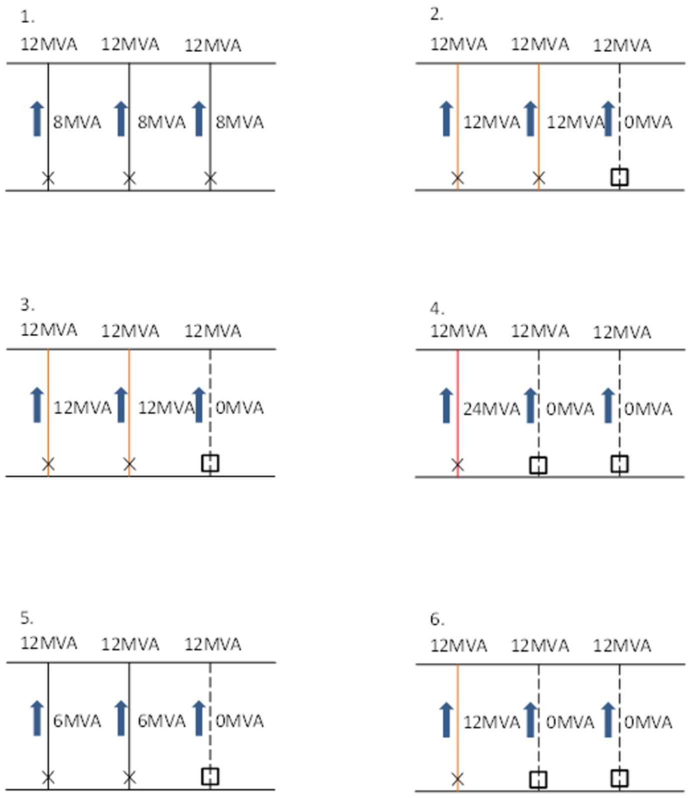


Figure 5: Pre-event limit scenarios

For a real network case the impedance and rating of each circuit is likely to be different, as a result more detailed analysis is required.

It is anticipated that the second pre-event load limit will be implemented, as a minimum, where the network is designed to operate in an N-2 condition, based on the parameters set out in P2/7 and in order to maintain network integrity.

6. Commissioning Process

a. Preparatory works

Information from the G99 application form and design submissions will be used to configure the new connection within the central ANM system. During construction the CCP settings will be implemented and confirmation sought to confirm the connection can meet the default response times – e.g. full constraint within 10 seconds.

The settings will be applied in line with 5.a and confirmation will be sought to confirm the correct implementation of this during commissioning.

If a site has multiple exit points a bespoke CCP configuration will be required. All sites must provide their own CT and VTs for monitoring, those within NGED's CCP cannot be used.

A connection is only possible once the required ANM system is established. NGED endeavour to commission ANM systems prior to planned connections however this is not always possible.

For connections where the ANM system is already established at least 6 months notice is required by NGED ahead of the desired connection date to allow sufficient time to update and configure the ANM system to include a new connection. If this is not given NGED cannot guarantee the full output capacity of a connection will be available.

The cost of commissioning a new connection onto the ANM system will be passed on to the customer. This will be included within the initial offer.

b. Testing

Prior to energisation testing specific to ANM is required to confirm the correct response of the new connection to the signals from the CCP. Various tests will be carried out by NGED but a response will be expected for some of these, which will include:

i. Stage 1 applied locally and remotely: Testing that the Stage 1 Customer Confirmation is received & the import/export of the site adheres to the predefined Stage 1 value within the required time. Testing to confirm the import/export is restored when the Stage 1 signal is reset.
ii. Stage 2 applied locally and remotely: Testing that the Stage 2 Customer Confirmation is received & the import/export of the site goes to 0MW & 0MVAr following the opening of the customers G99 circuit breaker. Testing to confirm the circuit breaker closes and the import/export is restore when the Stage 2 signal is reset by the NGED control centre.
iii. Stage 0 applied in SCADA mode and ANM mode: Various set points will be sent over the 4-20mA signal interface (across the multiple channels if appropriate). These tests are to confirm the connection correctly interprets the mA signal as defined in 5.a, which if not correct configured will lead to regular spurious application of Stage 1. The ramp rate of the connection will also be assessed to ensure it is within the required setting applied on the CCP. Multiple non-zero set points will be applied and a zero MW/MVAr set point will be applied.

7. On-going operation

a. Reporting

In line with the requirements of Access SCR from April 2023 NGED will report on the level of curtailment experienced by a connection. The curtailment counted towards the curtailment limit will be based on the time at which the active set point is below the maximum set point.

b. Real time cause of curtailment

NGED's Control Centre have visibility of the topology and loading of the network, which will allow them to view the state of the network. The ANM system's normal operation is fully automated following the state of the network and curtailment is likely to be increased during an outage. Therefore the Control Centre may be able to give an indication of the cause of curtailment but NGED do not offer a service to provide feedback on the cause of every curtailment event.

c. Maintenance

Periodic maintenance will be required on both the communications and electrical network which will require full curtailment for an extended period of time. This limitation of access will not be included towards the count of the Curtailment Limit.

d. Abnormal running

If the network enters an unknown or abnormal state all ANM connections will be fully curtailed. This can be triggered by a wide area loss of communications, an exceptional number of outages (beyond the requirements of P2/7) taken on a network or for example the transfer of a substation to another GSP.

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