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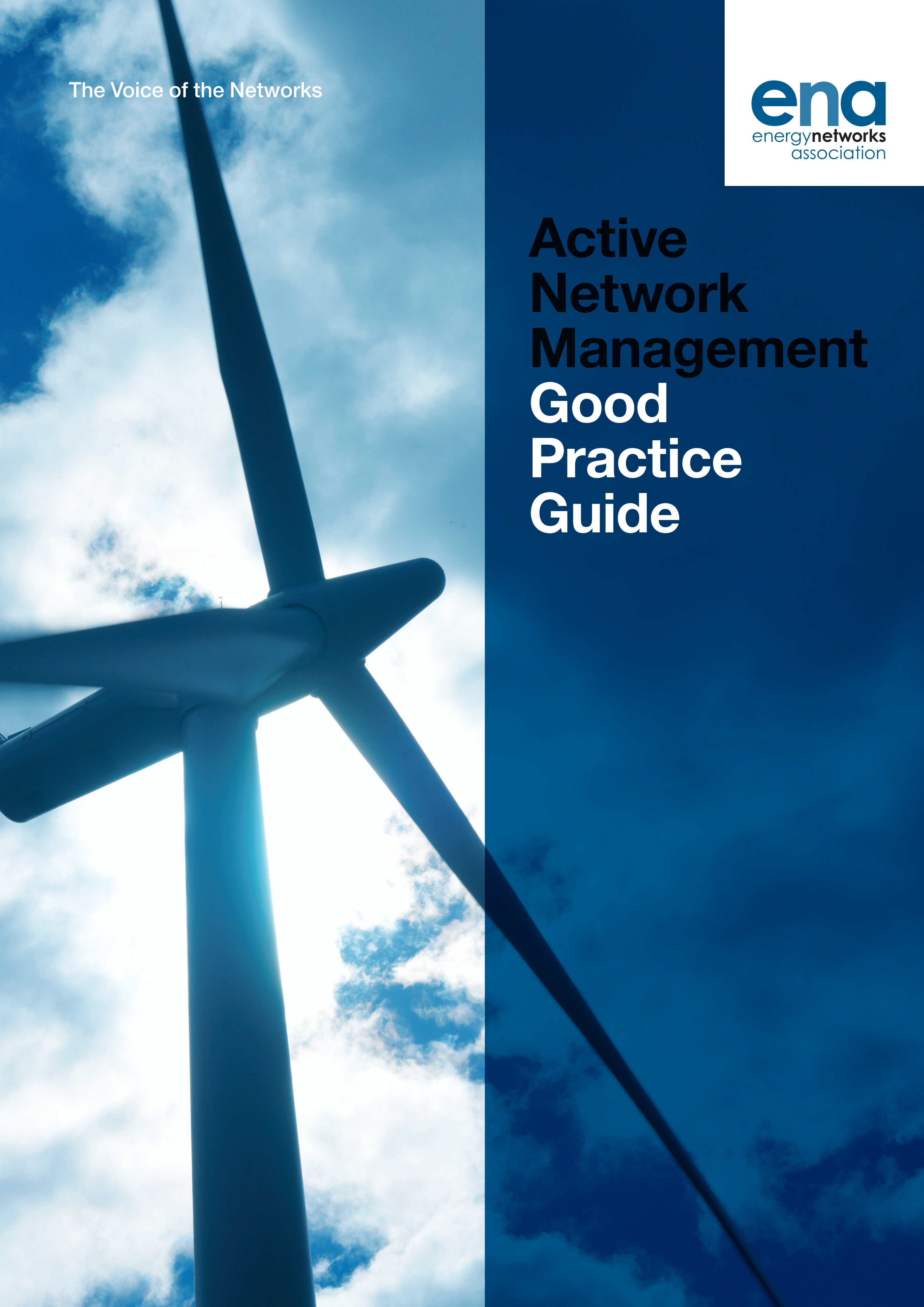
Active Network Management Good Practice Guide



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Active Network Management Good Practice Guide

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Executive Summary

Traditionally distribution networks have been predominately passive with electricity generated centrally flowing from the transmission system to customers connected to the lower voltage networks. However, with the growth of embedded generation at all voltage levels, and new smart technologies, Distribution Network Operators (DNOs) have the need to and, through Active Network Management (ANM) and the wider development of smart grids, the means by which to more actively manage flows on their networks. Unlike the DNOs, the Transmission System Operator (TSO) does manage the network in real time. ANM may nevertheless also have applications on the transmission network.

This Good Practice Guide for ANM has been commissioned by the Energy Networks Association's ANM Working Group to consolidate learnings so far from the deployment of ANM schemes in Great Britain. The guide sets out current good practice for the commercial arrangements and technical deployment of ANM technologies, and is intended to be of use to a number of electricity system stakeholders, including the network operators themselves, customers, product manufacturers, regulators and policy makers. The guide also looks to the future, and how ANM may become more commonplace and the implications for future network systems operations.

There is to date no industry-agreed definition of ANM, but for the purposes of this guide, the following summary definition is used:

Using flexible network customers autonomously and in real-time to increase the utilisation of network assets without breaching operational limits, thereby reducing the need for reinforcement, speeding up connections and reducing costs.

There is considerable momentum within the GB electricity industry towards the implementation of ANM. Most GB ANM schemes to date have been initiated as innovation projects, but ANM is already becoming Business as Usual for a number of DNOs.

ANM can be used with both generation and demand customers on the transmission and distribution networks, but the most common use to date has been by DNOs offering "ANM connections" to generators wishing to connect to constrained parts of the network. ANM connections allow generators to connect more quickly and at lower cost by including provisions for curtailing their output during constrained periods to avoid the need for reinforcement.

ANM connections raise a number of questions for network operators and customers, including:

> Whether ANM is technically and economically viable on a given part of the network
> Under what circumstances customers should be curtailed and how much curtailment customers should expect at the time of connection and in the future
> Whether ANM is a temporary or an enduring solution, and how any future reinforcement costs are recovered
> What information should be shared with customers, what obligations they have, and the impact of the ANM connection design on project bankability.

Good practice in this area involves providing a clear connection process and relevant information to customers, and ensuring that principles of access are future-proofed.

ANM can also have applications for existing customers with conventional connection agreements. Some networks require reinforcement for reasons other than new connections (e.g. organic load growth on an import-constrained network or the loss of a large demand customer on an export-constrained network). Network operators can use ANM to vary customer demand or generation by entering into commercial agreements with customers or aggregators, allowing them to reduce network peaks and defer or avoid planned reinforcement. In the future, similar arrangements may allow DNOs and National Grid to use ANM to access a wider range of network balancing services. Good practice in this area involves ensuring that this is evaluated as an option alongside traditional reinforcement, and implemented where beneficial.

There are a number of technical and process considerations when deploying ANM. The technical integration of ANM involves physically embedding a scheme into a DNO's existing electrical and communication infrastructures, as well as into its network operations and management practices. The system architecture of an ANM scheme will define to a large extent how it is integrated with existing network systems. Control room visibility and network safety considerations are critical to the operation and management of networks and will determine the interfacing requirements. ANM is likely to affect a number of key functions across the DNO, requiring process and operating model changes, and training on a range of topics. Good practice in this area involves ensuring that the ANM scheme is safely and efficiently integrated into systems and processes.

ANM is expected to increase the need to coordinate operations across the distribution and transmission systems. As well as allowing more embedded generation onto the network, ANM schemes can interact in unpredictable and undesirable ways with balancing actions taken by National Grid. In order to mitigate this risk, inter-network protocols should be identified now to ensure interactions between networks are managed effectively and efficiently.

ANM technology and smart grids more generally are expected to evolve considerably in future, which may allow them to be used in a broader set of applications. It is also expected that the increasing presence of generation, storage and flexible demand on the distribution network will both necessitate and facilitate a Distribution System Operator role, whose interaction with the Transmission System Operator will need to be well defined.

Good Practice Summary

ANM connection design

> Principles of access can either be on a Last-In-First-Out (LIFO) or pro-rata basis:
  – LIFO may be preferred in situations where early projects are looking for certainty and simplicity
  – Pro-rata may be preferred where maximising connections is an objective and applications are reasonably concurrent
> If adopting pro-rata approach a quota should be defined
> If ANM is intended to be a temporary solution, the costs of reinforcement should be included in the connection agreement, especially under LIFO where customers will be exposed to different levels of curtailment

ANM connection process

> Guides and tools should ideally be made publicly available in a simple and clear format to help customers understand ANM connections
> ANM connection offers should follow conventional offers, but network operators may notify a customer that they are eligible upfront
> Information about the current and future network could be included in the connection offer as appropriate, with individual assets anonymised as necessary
> Once connected, network operators may give notification of curtailment, periods when the scheme is active, and any changes to the scheme as necessary
> Network operators should make clear to customers that they should carry out their own due diligence on the risk of curtailment, taking into account information provided by the network operator, but recognising the impact of unforeseen events (e.g. changes to network demand, technical failures, severe weather)

Transmission ANM

> ANM should be considered where Enabling Works are seen to be too costly or take too long
> ANM should only be used on radial elements of the network, where its impact on network operation can be easily understood
> Although it is currently expected that ANM connections on the transmission network will be used as a temporary measure, its use as an enduring solution could be considered if justified by a Cost Benefit Analysis
> Where possible, the parties bearing the cost of curtailment should be the same as the parties avoiding the cost of reinforcement, thereby ensuring the correct economic incentives are in place

Deferring general reinforcement

> A network operator's Planning team should be able to carry out a quick assessment of planned reinforcements to assess their possible suitability for deferral using DSR, perhaps with a unified database or a tool
> There should be regular communication between the Planning, Connections and, where required, a dedicated DSR function to identify and assess plausible candidate DSR sites (if this service is not provided by a 3rd party)

- A technical feasibility assessment should be carried out, taking into consideration the nature of the constraint, the number and types of assets behind that constraint, the DSR each might be able to deliver and the contribution that this could make to security of supply
- An appropriate economic case should be made each time DSR is considered
- Some form of regular audit may be required to ensure that the achieved DSR is delivering the expected response at the intended cost, and that the business case for DSR remains valid
- ANM can also be used following a fault to manage the restoration of customer supply, allowing more of the latent network capacity to be used with minimal impact on consumers

System architecture

- A centralised architecture is preferred to manage wider network constraints
- A decentralised architecture is favoured where response times more rapid than a SCADA (Supervisory Control and Data Acquisition) system's capabilities are required
- A "hybrid" approach can improve overall ANM scheme reliability by having improved communications redundancy over decentralised architectures and removing the "single point of failure" feature characteristic of centralised architectures

Functional Specifications

- Where existing communications assets are to be used, the network SCADA measurement and polling rates should be assessed for their suitability to support the ANM scheme performance requirements. Alternatively, modifications could be made, or new assets may be required
- The latency and reliability of ANM operation should be assessed to ensure this will not adversely affect scheme efficacy. Curtailment thresholds may include a buffer to account for the latency of the ANM system.
- DNOs should specify what existing systems and protocols the ANM scheme must be capable of interfacing with
- There should be adequate communications redundancy as appropriate for the application
- Consideration of security issues and network protection are needed prior to deployment

Control room

- Control engineer responsibility should be agreed in the early stages of the integration process to ensure the correct SCADA notifications and controls are provided
- A Human Machine Interface (HMI) "dashboard" should be provided within the Network Management System with ANM scheme overview
- Controls should be made accessible from within the HMI
- Adequate training and familiarisation should be provided to control engineers on ANM scheme operation and accompanying HMI

ANM failsafe modes

- Failsafe modes must be integral to an ANM scheme algorithm
- Non-responsive generation is disconnected or constrained to failsafe level
- Generation is disconnected or constrained to failsafe level upon loss of communication unless back-up communications are available
- Generation is disconnected or constrained to failsafe level upon loss or disabling of the ANM scheme
- Failsafe level of generation is 0 MW but this could change in future owing to local considerations and constraints

People and Processes

- ANM affects multiple stakeholders within a network business, each of whom would ideally be brought on board early in the implementation to smooth the transition
- Suitable business owners in each department should be identified to coordinate the ANM scheme
- A central ANM team will help with coordination efforts, but does not need to be a large function until the ANM scheme is more fully implemented
- Effective training will be important, and may take the form of formal training, ongoing support, manuals, user guides or tools
- Training will need to cover a wide range of subjects including technical proficiency, commercial negotiations and data management

Network interactions

- Inter-network protocols should be identified to ensure interactions between networks are managed effectively and efficiently
- If the TSO is to have influence over distribution ANM, this should be reflected in the customer's connection agreement
- Information exchange should focus on understanding how ANM will behave rather than communicating real-time information about specific ANM actions
- In order to allow the Balancing Mechanism (BM) to operate effectively, ANM behaviour must change in response to BM actions in the same network zone

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Introduction

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Traditionally distribution networks have been predominantly passive with electricity generated centrally flowing from the transmission system to customers connected to the lower voltage networks. However, with the growth of embedded generation at all voltage levels, and new smart technologies, Distribution Network Operators (DNOs) have the need to and the means by which to more actively manage flows on their networks[1]. Unlike the DNOs, the Transmission System Operator (TSO) does manage the network in real time. Active Network Management (ANM) may nevertheless also have applications on the transmission network.

The concept of Active Network Management (ANM) has been interpreted in different ways, but the core principle is that the electricity produced or consumed by network customers is variable, and that DNOs can make use of that variability to optimise the usage of network assets. This can speed up connections and reduce costs, primarily for the benefit of those customers who are able to provide flexibility. The earliest ANM schemes in Great Britain have been implemented as part of innovation projects, but some DNOs are beginning to integrate such approaches into their Business as Usual practices.

The Energy Networks Association's ANM Working Group was formed in late 2013, comprising representatives from the UK DNOs and National Grid. Its aim is to develop consistent understanding in the emerging method of ANM and its application on electricity networks across Great Britain (GB). The group has commissioned this Good Practice Guide (GPG) for ANM with the aim to:

- Provide a common understanding of ANM, identifying considerations and issues to overcome when deploying ANM at all voltage levels
- Highlight case studies to use as reference points whilst informing a common understanding amongst network operators[2]
- Create and consolidate initial reference material from network operator experience to date, to inform future standards and recommendations

This guide is intended to be of use to a number of electricity system stakeholders, including:

- The network operators themselves, as a means of consolidating the learning to date, and understanding the interactions between their ANM schemes and the wider network
- Customers that might be offered ANM connections or to participate in ANM-enabled Demand Side Response (DSR), to help them to understand the information being provided by the network operator, and to understand any additional risks they might be taking on
- Product manufacturers who may be providing ANM equipment to the network operators, or equipment that may need to interact with ANM systems
- Regulators and policymakers, who may want to understand the economic drivers behind ANM, the benefits that such approaches can bring to consumers, how the benefits and costs accrue to different market participants, and any risks that ANM might present

This Good Practice Guide represents a snapshot of the current state of ANM, based on the understanding that has been built up to date. The "good practice" it espouses may evolve as ANM becomes more standard, and as the commercial and regulatory environment changes. The guidance therefore reflects a best view of the current reality for the network operators. Some consideration of the future of ANM, in the context of other expected developments on the distribution networks, is given at the end of the guide.

The guide comprises the following sections:

- Section 2 defines ANM and identifies its high-level policy based and economic drivers
- Section 3 explores the key ways in which ANM can be used, including connecting customers more quickly and cheaply, and as a means of deferring network reinforcement
- Section 4 considers the technical, data, people and process changes required to embed ANM schemes within a network operator's business
- Section 5 explores the way in which ANM schemes operate on distribution and transmission networks, and explores some of the interactions related to system operation between networks
- Section 6 considers the future of ANM, exploring how the technology might evolve, the changing regulatory environment, the emerging Distribution System Operator (DSO) role and the future services that ANM might be able to provide
- Appendix A gives a glossary of terms used in this guide
- Appendix B summarises the examples of ANM schemes used to inform this guide

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[1] Unless otherwise specified, this guide refers to the use of ANM on the distribution network. The use of ANM on the transmission network is addressed in Section 3.2.4 and throughout Section 5.

[2] "Network operator" refers to DNOs, Transmission Owners (TOs) and Transmission System Operator (TSO)

What is Active Network Management?

2

2.1
Definition

Active Network Management (ANM) is a core part of the concept of a 'smart grid'. There is to date no industry-agreed definition of ANM, but some themes emerge from the ANM literature[3]:

> **Function**: ANM is used to "manage network constraints"[4], to "maintain networks within their normal operating parameters"[5] or to "control and [manage] network equipment and the devices they serve in normal conditions to enhance the utilisation of the network assets and minimise the requirement for their reinforcement"[6].

> **Timing**: Under the majority of interpretations, ANM schemes respond in real-time to a given trigger. Most applications of ANM, and at least one definition[5] see it used pre-emptively to prevent a network overload. However, ANM systems are being used in a post-fault setting to restore customers following a fault, and could be used post-fault in real time to bring a system back within its normal or acceptable operating parameters.

> **Monitoring & information**: In order to respond rapidly, the ANM system needs to monitor the state of the network in real-time (or close to it). In some cases, modelling and forecasting may be used to anticipate the future state of the network or to fill any gaps in the monitoring through estimation.

> **Autonomy**: Following the initial configuration, there is minimal involvement from human actors in the real-time decision making, although manual intervention may be used to change the decisions that the ANM will make in future (e.g. changing set-points or post-fault switching).

> **Location**: An ANM scheme can be either decentralised or centralised, with remote devices performing algorithms in decentralised schemes and centralised schemes being more embedded within central network control.

> **What ANM controls**: ANM can make use of customers connected to the network such as generators, demand or energy storage devices. The definition can be extended to include DNO-owned network assets such as transformers and Power Electronic Devices[7] to provide a wider range of network services[8].

Whilst there are a number of valid interpretations of ANM, and as noted above ANM is not limited to the control of customer-managed assets, for the purposes of this guide, the following summary definition is used:

Using flexible network customers autonomously and in real-time to increase the utilisation of network assets without breaching operational limits, thereby reducing the need for reinforcement, speeding up connections and reducing costs.

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[3] Note that Smart Grid Architecture Model (SGAM) mapping may provide an efficient way of representing different ANM schemes

[4] Ault, G. (2013) Tutorial: Active Network Management, SGS, Online: http://www.cigre-thailand.org/tncf/events/smartgrid_15feb2013/cigre_thailand_anm_tutorial_ault__by_graham.pdf

[5] Douglas et al. (2007) Overview of Active Network Management Developments and Practices in Great Britain, CIRED 19th International Conference on Electricity Distribution

[6] Currie et al. (2007) Painting a clearer picture, IET Power Engineer:p.42-43

[7] PEDs can be used in power circuits to convert or control electric power (e.g. switching or amplifying flows)

[8] For example, using ANM to reduce losses by using frequent use switches to dynamically optimise Normally Open Points (NOPs) according to daily or seasonal load variations between adjacent circuits, or using a quad-booster to dynamically optimise load sharing between circuits.

2.2
Key terms

As with the definition of ANM itself, the terms relating to ANM are not fully agreed within industry. For the purpose of this guide, a number of key terms have been defined[9]:

> **Conventional connection**: The standard means by which customers are connected to the distribution network, which is to say without ANM-based curtailment forming part of the connection agreement

> **ANM connection**: Typically offered on a constrained part of the distribution network, this is a connection made on the condition that ANM be able to curtail the customer's import or export in order to alleviate that constraint

> **Customer**: Any generator, demand or storage asset that is connected to the electricity network

> **Principles of access**: The rules that define the customer's rights to access network capacity, and the terms under which the customer's rights may be curtailed to alleviate network constraints

> **ANM-enabled zone**: A region of the network that has had the necessary equipment installed to allow ANM connections to be offered

2.3
What is driving the growth in ANM?

There appears to be considerable momentum within the GB electricity industry towards the implementation of ANM, as evidenced by the number of DNOs rolling it out. The economic drivers on the different market participants are considered in some detail in Section 3.1.4, but at a high level there are some key reasons for this growth in ANM:

> **Providing connections quickly and cheaply**: DNOs are being encouraged (most notably by regulators and DG customers) to find ways to provide connections quickly and at lower cost. ANM connections are emerging as a means by which this can be done.

> **Facilitating renewables**: The connection of renewable generation is seen as a priority. The UK has committed to renewables targets, which will require connecting renewable generators to both the distribution and transmission networks, potentially more rapidly than network capacity can be expanded by conventional means.

> **Managing intermittent low-carbon technologies**: Power flows on the electricity networks are becoming more complex and unpredictable, driven by the uptake of small scale generation and other low-carbon technologies on the distribution network. By reacting in real-time, ANM provides a means to manage the associated network risk.

> **Reducing capital expenditure**: There is a general requirement to reduce the cost to customers of reinforcing, maintaining and operating the network. Operational solutions enabled by ANM have the potential, in certain circumstances, to be more cost effective and less carbon intensive than traditional capital expenditure approaches.

> **Technological readiness**: The monitoring, communications and computational technology required to implement ANM is now sufficiently fast, reliable and low-cost for ANM to be a viable means of achieving these objectives, and a number of innovation projects have been successfully demonstrated.

These drivers translate into a number of applications for ANM that may be of benefit to the DNOs and their customers. These applications are considered in Section 3.

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[9] A full glossary of terms can be found in Appendix A.

Applications of ANM

3

3.1
When and how should ANM be used?

3.1.1 Introduction

ANM can be used to increase the utilisation of constrained network assets where a customer's consumption or production can be flexed by limiting the import or export at the site. This section discusses where ANM is useful, who can provide it, and what the drivers are, as summarised in Table 1.

Table 1 Considerations for identifying when ANM should be used

When should ANM be used?	> Where can ANM be useful? What system conditions could benefit from the approach?
	> Who can participate? Which customers are technically capable of providing the required response?
	> What are the drivers? What incentives do the different electricity market participants have to see ANM enacted?
	> How should the costs associated with ANM be recovered?

3.1.2 Where can it be useful?

There are two main applications currently being considered:

> **Achieving faster and cheaper connections**, which has been trialled in a number of innovation projects including:

- Scottish and Southern Energy Power Distribution Orkney Registered Power Zone (RPZ)
- SP Energy Networks Accelerating Renewable Connections (ARC)
- UK Power Network Flexible Plug & Play (FPP)
- Western Power Distribution Lincolnshire Low Carbon Hub (LLCH)
- Northern Powergrid Customer Led Network Revolution (CLNR)
- Electricity North West Capacity to Customers (C2C)

> **Deferring general reinforcement of the wider distribution network** via the use of commercial arrangements with existing customers as trialled under:

- Western Power Distribution Flexible Approaches for Low Carbon Optimised Networks (FALCON)
- UK Power Network Low Carbon London (LCL)
- Electricity North West Capacity to Customers (C2C)

These two applications are the focus of this section of the guide. Whether being used to connect more customers or managing existing customers to defer general reinforcement, operationally the function of ANM is the same: it manages net load in close to real time when a constrained part of the network would otherwise exceed its firm capacity[10], as illustrated in Figure 1.

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[10] A network's firm capacity is the load it can carry following one or more faults (i.e. less than the total capacity). An "N-1" network operating within its firm capacity is able to continue delivering power to customers without loss of service following a single network fault. For the purposes of this section it is assumed that ANM is used to keep the network within its firm capacity, or to use the latent capacity by managing the way customers are reconnected following a fault. It may be possible to utilise ANM immediately after a fault, in which case the intact network may be allowed to exceed the firm capacity in some instances. This possibility is explored in Section 6.

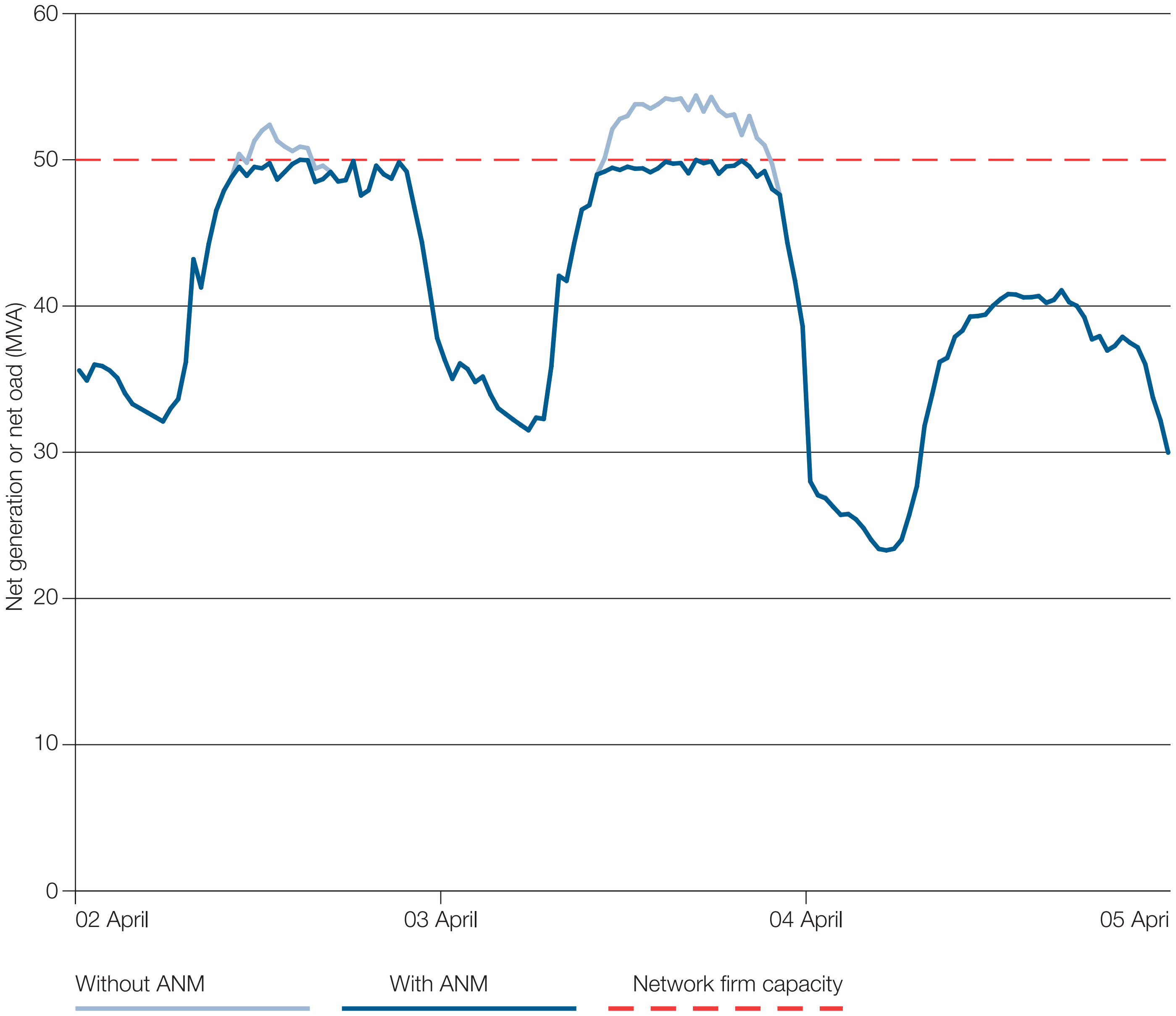

Figure 1 Using ANM to keep a network within its firm capacity

ANM can also be used to control the way in which customers are reconnected following an outage, as was demonstrated in Electricity North West's C2C project. In this case, new and existing customers agree to accept delays to their restoration following a fault, in return for a fee or reduced connection charges. This allows the DNO to increase the efficiency of the overall restoration procedure, and thereby allows more customers to be connected with only a minimal impact on the level of service.

In the future, ANM may also have some ancillary applications such as providing balancing services to the Transmission System Operator (TSO), National Grid. These potential uses are discussed in more detail in Section 6.

3.1.3 Who can participate?

In principle, any customer could be eligible for an ANM connection, provided it is in an area that is or can be ANM-enabled. There may, however, be practical and financial considerations that exclude some customers. For example, it may not be economic to install ANM for smaller customers. As the technology becomes cheaper, it is expected that the size of customer for which an ANM connection is viable will reduce.

Aggregating smaller customers into curtailment groups may be possible, and has been trialled in a limited sense under Electricity North West's C2C project. In principle, multiple customers would be managed simultaneously by a single ANM unit. Some on-site equipment would be required to deliver the required change in import or export, but it is assumed that this approach would be less costly than having each customer being managed individually.

There may be other physical characteristics that make a customer more or less suited to an ANM connection agreement. For example, the response time will affect the DNO's ability to alleviate any constraint, particularly if the other customers on the network have unpredictable profiles as is increasingly the case on networks with large volumes of intermittent generation. It will be the DNO's responsibility to ensure that the customer response characteristics are adequate to match the variability expected in the flows on the network, and this may exclude these customers from participation in ANM.

3.1.4 What are the drivers?

Although the use of ANM under its two main applications is similar, the motivation for employing it in each case differs:

> **Enabling faster & cheaper connections**
Some customers would prefer not to wait for a reinforcement to occur before connecting. In this case, ANM potentially allows them to connect more quickly, perhaps as a temporary solution until the reinforcement has occurred.

In other cases the reinforcement costs associated with a conventional connection can be prohibitively high. Without ANM connection offers these projects would not be viable. By being offered an ANM connection (assuming the DNO is able to do so), the connection cost could be reduced, allowing a development to proceed[11].

Without ANM it is possible to connect customers under an intertrip arrangement, which allows the DNO to protect the network[12]. Because this results in a disconnection rather than curtailment the impact on customers is often more significant.

> **Using existing customers to maximise network utilisation**
In this case the DNO uses the flexibility of existing demand or generation to avoid or defer general reinforcement either by flattening network peaks or utilising latent network demand. The decision to use ANM is the DNO's and will depend on its regulatory incentives, but ultimately the decision should be based on the relative costs and benefits of deploying an operational ANM-enabled solution ahead of network reinforcement, or as a permanent solution.

The different costs, risks, direct benefits and incentives to customers and DNOs under each of the applications are summarised in Table 2.

[11] This assumes that the loss of revenue that occurs as a result of curtailment is less than the cost reduction achieved by opting for ANM connection rather than a conventional connection

[12] An intertrip scheme automatically disconnects a generator or demand following a system fault to relieve localised network overloads. The intertrip protection device is located at the point of generation or demand connection and is activated in response to a local system fault. Network protection consists of a range of field devices that can operate automatically and/or be controlled manually from the control room to isolate and then restore areas of the network following a fault. ANM schemes differ from intertrip schemes and network protection in that they provide granular control of generation outputs to achieve more efficient use of the network whilst ensuring compliance with security of supply standards during a maintenance outage or fault.

Table 2 Benefits, costs and risks to customers and DNOs

		Direct benefits & incentives	Costs & risks
Enabling faster & cheaper connections	Connecting customers	> The reduction in connection costs under an ANM connection agreement (which embodies any reduced reinforcement expenditure, offset against the cost of installing the ANM kit) > The additional revenue that can be secured in the early years by connecting more quickly	> The increase in expected curtailment under an ANM connection agreement as opposed to a conventional connection agreement, and the annual revenue loss to which this corresponds > The long-term risk that the business case could be eroded by increasing curtailment over time
	DNO & DUoS customers	> Regulatory framework offers some broad incentives for speeding up connections such as customer service, and some connection-specific incentives such as time to connect and customer engagement > A small proportion of wider reinforcement typically cannot be recovered from connecting customers, so to the extent that this is reduced by ANM this could be a benefit to DNOs and existing customers paying to access the network through Distribution Use of System (DUoS) charges	> ANM setup costs not associated with a particular connection, which could escalate if fewer customers take ANM connections than had been anticipated > The increased complexity could affect outage rates and restoration times, which would penalise DNOs via the Interruptions Incentive Scheme (IIS) > Increasing circuit utilisation could reduce the ability to take planned outages for maintenance > Interoperability of multiple ANM schemes could increase network risk
Using existing assets to maximise network utilisation	Customers providing flexibility	> Commercial terms would offer financial incentives for flexibility providers (e.g. availability and utilisation payments)	> For flexibility providers, any loss of earnings (e.g. from core business activities, or through degradation of generation assets) could exceed that expected when agreeing commercial terms > In cases where backup generation is being used, there is an increased risk of loss of service for customers
	DNO & DUoS Customers	> Strategic value from delaying or optimising reinforcement capital expenditure (capex), and reducing the risk of stranded assets if forecasts change > DUoS customers share benefit of reduced reinforcement capex with the DNO via efficiency incentives	> Finding customers and negotiating commercial agreements > Installing ANM on their sites and integrating with the wider system > Any payments that may be made to customers as per the commercial agreement (e.g. availability and utilisation)

3.1.5 How should the costs of ANM be recovered?

It is expected that considerable effort will be required to implement an ANM system. The costs incurred in making the transition to Business as Usual can be as high as the R&D costs required to develop the system itself. These costs need to be recovered by the DNO, along with any additional costs associated with a particular ANM scheme.

It is useful to distinguish between two types of cost:

> **One-time costs**: Some costs need to be incurred upfront, but do not change regardless of the number of ANM schemes enacted (e.g. upgrading the control room, and changing operational processes).

> **Scheme-specific costs**: these may arise solely as a result of a particular ANM scheme (e.g. on-site ANM equipment) or, whilst not being attributable to one scheme, escalate as more schemes are added (e.g. upscaling central ANM equipment, or expanding the customer services team).

One-time costs could in principle be attributed to individual schemes. However, this would rely on determining the relevant portion of costs to attribute to each customer, which will depend on the number of ANM connections agreed in future. It would also need to be agreed how to split these costs between newly-connecting customers and other ANM schemes such as using existing customers to manage network peaks. It would be more practical to include these costs as overheads to be passed to consumers through DUoS charges.

Scheme-specific cost recovery may differ depending on the application:

> **Enabling faster & cheaper connections**
In the case of connections, an ANM-connected customer could be charged for the ANM equipment they require and any associated increase in overheads, just as they would be charged for costs incurred under a conventional connection agreement.

> **Using existing customers to maximise network utilisation**
Schemes of this sort (e.g. DSR or the control of storage assets) should only be implemented if the overall benefit outweighs the cost. The scheme-specific costs of ANM therefore should be associated with the scheme. In this case, the cost of ANM is recovered through the avoided cost of reinforcement (with the net benefit being shared with consumers).

Sections 3.2 and 3.3 go into more detail on each of these two core applications. Based on the innovation projects and the DNOs' broader experience to date, the sections identify good practice that could be applied when designing and running the systems and processes in order to make the best use of ANM.

3.2
Enabling faster and cheaper connections

3.2.1 Introduction

ANM can facilitate the connection of new generation and demand to the distribution network in areas where conventional connections would either be slow or prohibitively expensive. To date, DNOs have mostly used ANM to connect renewable generation, and have built up considerable knowledge in this area from both innovation projects and, more recently, from offering these novel flexible connections as part of standard business practice.

The following sections therefore focus on the connection of generation on the distribution network. However, whilst there is less experience in using ANM either on the transmission network or for connecting demand customers, these remain viable options. Section 3.2.4 therefore considers how ANM differs when connecting to the transmission network, whilst Section 3.2.5 considers how connecting demand differs from connecting generation.

Under a conventional connection, the DNO will assess the level of reinforcement required, if any, and indicate to the customer the cost[13] and the time required to complete the works. The customer can then:

- > **Agree to the terms**, paying for the direct reinforcement costs, and waiting for the reinforcement to be completed before it can be connected to the network, or
- > **Attempt to share the costs**, either by establishing a consortium agreement, or by delaying the project, anticipating that another customer will wish to connect to the same part of the network, thereby allowing some of the costs to be shared as per the Common Connection Charging Methodology (CCCM)[14]

ANM allows for an additional approach where the generator can connect ahead of the associated network reinforcement:

- > **Agree an ANM connection**, allowing the DNO to curtail the export from that customer in order to alleviate a network constraint that it would otherwise have caused.

An ANM connection offer may be made in a network zone[15] that is already ANM-enabled, or it may be that a zone needs to be made ANM-enabled before the ANM connection can be made. Whether to make a zone ANM-enabled depends on a number of factors, including the expected number of ANM connections that would be made.

3.2.2 Should a network zone be ANM-enabled, and how?

Assuming that a DNO has implemented the capability to integrate ANM into its central systems and processes, it then needs to decide where it should be applied. The driver for making a network zone ANM-enabled ultimately comes from connecting customers. However, DNOs may be proactive, seeking out zones where ANM could be beneficial, or reactive, responding to requests by potential customers. In either case, the DNO needs to determine whether ANM is suitable. Table 3 gives a checklist of key questions that a DNO may wish to ask when deciding on whether to implement ANM in a particular zone.

Table 3 Checklist for making a zone ANM-enabled

Whether to make a network zone ANM-enabled	> Is the zone at or approaching capacity?
	> Is there a demand for connections?
	> Is conventional reinforcement too slow or prohibitively expensive for customers, and is ANM likely to be an acceptable alternative?
	> Are there any technical or regulatory barriers to using ANM? Could ANM have an adverse influence on the rest of the network?

Table 4 Considerations for implementing ANM

How to implement ANM	> What are the principles of access, and hence what is the logic for curtailing customers?
	> Is ANM intended to be a temporary or enduring solution? If temporary, what are the transition arrangements?
	> Is there a need for a volume-based connection limit?
	> Does the limit trigger reinforcement, and how are costs recovered?

Having decided to make a network zone ANM-enabled, the DNO has a number of choices to make regarding the design of the ANM scheme in that zone. Some key considerations are summarised in Table 4.

3.2.2.1 Whether to make a network zone ANM-enabled

In order to make a network zone ANM-enabled, the following criteria will need to be met:

- > **The network zone is at or approaching a constrained state**. Most likely it will be the case that an additional conventional connection would lead to a requirement for network reinforcement. DNOs may need to verify that existing firm and intertrip generators' export profiles are consistent with their connection agreements, and that they are not utilising capacity allocated for other generators.
- > **There is evidence that a number of customers wish to connect** to that part of the network. Without this evidence, there is a risk that the ANM system would be under-utilised, and may impose large costs on a small number of customers (or have to be absorbed by the DNO and customers more broadly). Decisions may be made on the basis of connection requests, but it should be noted that the connections process is dynamic. It is necessary, therefore, to ensure that the decision to install ANM is based on the latest information, and remains robust if not all requests proceed to connection.

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[13] Allocation of costs is defined by the Common Connections Charging Methodology (CCCM). In short, the connecting customer will be required to pay for the cost of the "Minimum Scheme" (the lowest capex scheme able to provide the required capacity), excluding any reinforcement carried out greater than one voltage level above the voltage at the Point of Connection to the existing Distribution System (provided reinforcement costs are below the £200/kW High Cost Cap).

[14] Sharing will occur provided the projects connect within five years of each other, as per CCCM paragraph 5.29: "Recovery of costs for previous works"

[15] "Zone" here means any part of the network that contributes to a given constraint, such as all parts of the network served by a constrained substation

- > **It is expected that customers would be unwilling or unable either to wait or pay for the reinforcement** that would be required for a conventional connection, and would be willing to consider ANM. This may be known because a series of conventional connection offers have been declined, or as the result of active surveying of potential customers. Reinforcement expenditure may be unjustifiable for any single customer, but acceptable if the costs can be shared under the rules laid out in the CCCM. Before opting for ANM, it could therefore be ensured that potential customers cannot take a consortium approach, coordinating their connections to take advantage of this cost sharing.

- > **ANM must be technically feasible and consistent with the regulatory environment**. Reasons why ANM may not be a suitable solution include:
  - The constraint type cannot be alleviated by current ANM technology, such as a fault level constraint[16]
  - The communications infrastructure (either local third party systems or the DNO's own equipment) is inadequate to apply ANM, and cannot be upgraded without incurring prohibitive costs
  - The potential customers are geographically remote, making ANM costly to implement
  - The mix of potential customers behind a constrained point on the network would not be able to alleviate the constraint because of their technical characteristics (e.g. response time or ramp down rate)
  - The use of ANM could introduce network issues (e.g. transient voltage instability)
  - The use of ANM could have adverse effects elsewhere on the network (e.g. transmission system) such as undermining TSO balancing actions taken on embedded generation in the ANM zone (see Section 5.2.2)

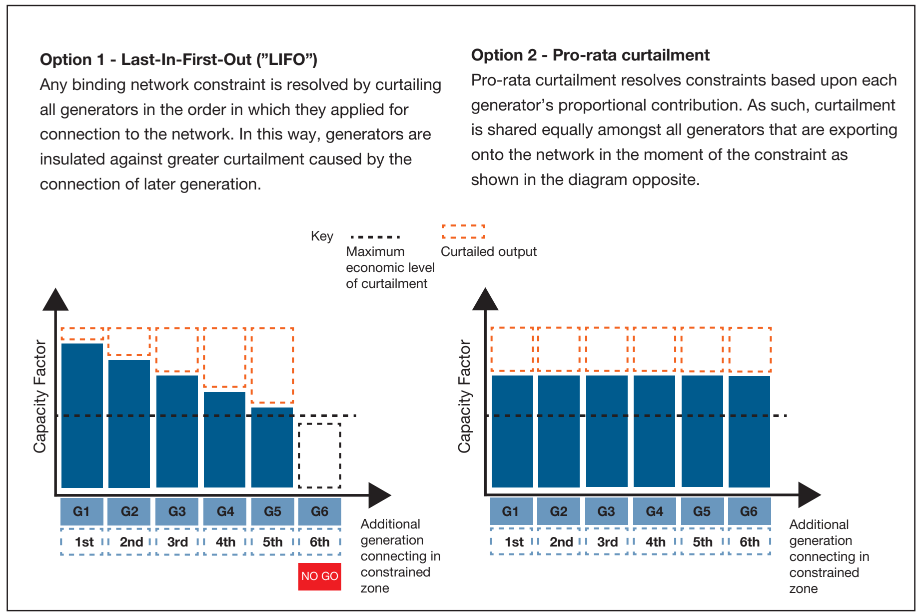
3.2.2.2 How to implement ANM in the network zone

Once it has been decided that a network zone is suitable for ANM, the DNO needs to decide how to implement the scheme. A DNO may choose to have a common approach for all ANM-enabled areas, or may alter the scheme either to reflect experience to date, or because of differences between network zones. In order to choose an appropriate design, the following questions need to be answered:

- > **What are the principles of access?**
  There are currently two primary candidates for curtailment logic:
  - Last-In-First-Out (LIFO), where generators are curtailed in reverse order of connection applications, which was trialled in SP Energy Networks' Accelerating Renewable Connections (ARC) project and Scottish and Southern Energy Power Distribution's Orkney RPZ
  - Pro-rata, where curtailment is shared across generators in an ANM zone, which was the preferred approach in UK Power Networks' FPP project

Both approaches were summarised in UK Power Networks' FPP Principles of Access report[17], which is replicated in Figure 2.

Figure 2 Principles of access: LIFO vs pro-rata



Option 1 - Last-In-First-Out ("LIFO")
Any binding network constraint is resolved by curtailing all generators in the order in which they applied for connection to the network. In this way, generators are insulated against greater curtailment caused by the connection of later generation.

Option 2 - Pro-rata curtailment
Pro-rata curtailment resolves constraints based upon each generator's proportional contribution. As such, curtailment is shared equally amongst all generators that are exporting onto the network in the moment of the constraint as shown in the diagram opposite.

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[16] This constraint occurs where the magnitude of the electric current expected to flow through network devices (e.g. switchgear) in the event of a fault exceeds the short term current carrying capacity of those devices. Some innovation projects, such as Electricity North West's RESPOND, are considering how to actively manage such constraints, as discussed in Section 6.

[17] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Flexible-Plug-and-Play-(FPP)/Project-Documents/FPP_Principles_of_Access_report_final.pdf

- > **Is ANM intended to be a temporary or enduring solution?**
  When implementing ANM in a zone, the DNO needs to decide whether this is a temporary measure or an enduring solution to managing a constraint:
  - If ANM is a temporary solution, it is assumed that reinforcement will ultimately occur. The trigger for this reinforcement, and the means by which the costs are recovered needs to be defined.
  - If ANM is an enduring solution there is no automatic assumption that reinforcement will occur. Either ANM connections are offered indefinitely, or some sort of quota or cap is imposed to limit the volume of ANM connections that can be offered in order to manage the risk of escalating curtailment for customers connecting early in the process.

- > **Is there a need for a volume-based connection limit?**
  Under both temporary and enduring approaches, the DNO has the option to provide assurances surrounding the maximum level of curtailment that can be expected. This is important for the generator in assessing its business case. Whether this is necessary depends on the principles of access chosen. As Figure 2 illustrates, the effect of each additional customer on existing ANM-connected customers' curtailment is different under LIFO and pro-rata, which affects whether a limit on connecting customers is required.

  - **Under LIFO** existing customers' curtailment is unaffected by new connections, so there is no need to impose a limit to protect these customers. Potential customers will use their own due diligence to determine at what point the expected level of curtailment becomes too high for their project to be viable, eventually choosing not to connect.
  - **Under pro-rata** existing customers' curtailment expectation increases as each new customer connects. These customers will require assurance that curtailment will not exceed some limit. Without this assurance there is a risk that customers will be unable to finance their projects.

  Although it is more important under pro-rata, the DNO may choose to impose a limit under either approach. This limit can take a number of forms, including:

  - **Customer quota**: Limit the total volume (in MW or MVA[18]) of customers that can be connected under ANM connection agreements. The precise level of curtailment will not be known, and remains a risk for customers. The quota may be differentiated by technology to encourage a diversity of customer types. For example, in a region dominated by wind generation, the relative contribution of solar photovoltaics (PV) to a constraint will be lower than an additional wind generator of equivalent capacity. This also means that under LIFO, such a solar PV customer could receive a lower curtailment estimate than an equivalent wind customer in a higher position in the LIFO stack.
  - **Maximum curtailment threshold**: Define a maximum level of curtailment to which a customer will be exposed. The DNO would attempt to keep curtailment below this threshold (by reinforcing, restricting new ANM connections, or providing financial compensation), but would need to underwrite the risk of excess curtailment, which they may be unwilling or unable to do under current regulatory arrangements.

- > **Does the limit trigger reinforcement, and how are costs recovered?**
  Having defined a limit on the volume of customers or the associated curtailment, two options may be considered:
  - **Stop offering ANM connections**: conventional connection offers can still be made, although it may be unlikely that a customer would be willing to incur the cost of reinforcement
  - **Reinforce the network to alleviate the constraint**: this would only occur if it were technically feasible and there were an economic justification for doing so (i.e. if the cost of reinforcement that would be imposed on ANM-connected customers were lower than the cost of curtailment that they would otherwise face)[19]

  If the reinforcement option is chosen, there is a need to recover the associated costs. How best to do this may depend on the principles of access chosen:

  - **Under LIFO**, different customers face substantially different curtailment, which affects their willingness to pay for reinforcement. The requirement to contribute must therefore be built into customers' original connection offer.
  - **Under pro-rata**, customers will face similar levels of curtailment, although this may differ by technology. This may mean that all customers are willing to pay for reinforcement when curtailment reaches the same level, in which case a pre-defined obligation is less important. However, without such an obligation a customer may choose not to pay, and may still benefit from reduced curtailment. Including an obligation may avoid this 'free rider' problem.

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[18] MVA is the total power flowing on a network (a combination of real and reactive power)

[19] One possibility is for a partial reinforcement with reduced, but non-zero, curtailment. This may be considered, for example, if the cost (or environmental impact) of a full reinforcement were substantially higher than a partial reinforcement.

3.2.2.3 Assessing the different approaches to offering ANM connections

The preferred principles of access may depend on which objectives a DNO prioritises. Table 5 identifies some criteria by which an ANM scheme might be judged, assesses LIFO versus pro-rata against these criteria, and makes recommendations on the ways in which each should be applied.

Table 5 Assessment of principles of access options

Criterion	Description	LIFO	Pro-rata	Recommendation
Bankability	Customers need some assurances over future revenues in order to secure financing for their projects	> Initial curtailment estimate should be unaffected by future ANM connections since they are lower in the “stack” (although may still be affected by other factors such as the connection of small-scale generation) > Gives customers confidence that they will achieve a minimum level of revenue > Does not mitigate against micro-generation uptake or demand reduction unless reinforcement is triggered by a curtailment threshold	> Initial curtailment will increase as future customers are connected > Requires a quota to be in place, to provide customers with a degree of certainty surrounding future maximum levels of curtailment > Does not mitigate against micro-generation uptake or demand reduction unless reinforcement is triggered by a curtailment threshold	> Either approach can be made bankable > If pro-rata is chosen, a connection quota or maximum curtailment threshold is recommended
Network utilisation	The network should accommodate as much generation as possible, particularly in the case of renewables	> LIFO favours customers at the top of the “stack” > Projects lower down the stack tend to become progressively less viable > Possible that early connectors’ returns are higher than strictly needed for project viability, at the expense of later applicants who are unable to achieve target rates of return	> Where some level of curtailment is acceptable then pro-rata may result in more projects being commercially viable, and hence greater volumes connecting	> Where some level of curtailment is acceptable, pro-rata may be preferable provided generators can be comfortable with maximum level of curtailment they may be exposed to
Efficient dispatch	Customers with the highest economic value of output (to generators, consumers or society) or lowest carbon intensity should be curtailed last	> The LIFO stack is not ranked according to economic value of output or carbon intensity > High value or low-carbon customers may be curtailed before low value or high-carbon customers	> Pro-rata curtails all customers by the same proportion > No means to give preference to high value or low carbon customers	> Neither approach in its simplest form leads to more efficient dispatch > Future options may include market-based approaches to reveal economic value of curtailment (e.g. trading access rights)
Paying for eventual reinforcement	If the plan is eventually to reinforce the network the means for paying for this reinforcement needs to be defined	> Willingness to pay will be dependent on a customer’s position in the LIFO stack > If voluntary, only low-placed customers would be incentivised, which may make reinforcement uneconomic	> All customers are similarly affected by curtailment > Similar incentive to reinforce, meaning reinforcement cost can be shared across customers	> Pro-rata achieves this objective without further incentive, but obligation is one way to solve ‘free rider’ problem > Under LIFO, the obligation to pay for any future reinforcement, and the payment terms, would ideally be reflected in the connection offer

Table 5 continued Assessment of principles of access options

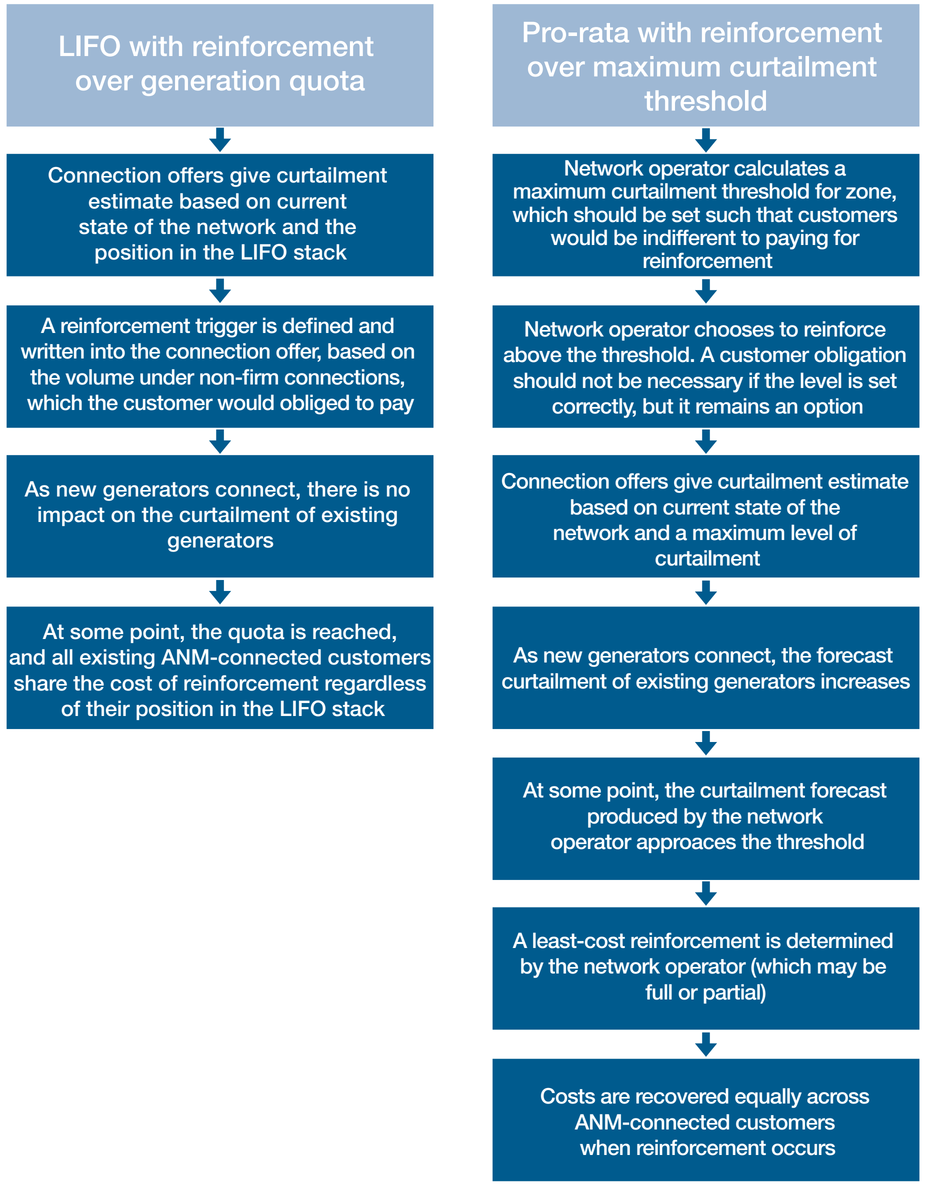
3.2.2.4 Examples of curtailment principles

By way of illustration, Figure 3 provides two examples of how either LIFO or pro-rata schemes can be designed to encourage connection and share costs relatively equitably amongst customers.

Section 3.2.2 Good Practice: ANM connection design

- > Principles of access can either be on a Last-In-First-Out (LIFO) or pro-rata basis:
- > LIFO may be preferred in situations where early projects are looking for certainty and simplicity
- > Pro-rata may be preferred where maximising connections is an objective and applications are reasonably concurrent
- > If adopting pro-rata approach a quota should be defined
- > If ANM is intended to be a temporary solution, the costs of reinforcement should be included in the connection agreement, especially under LIFO where customers will be exposed to different levels of curtailment

Figure 3 Two potential versions of curtailment principles

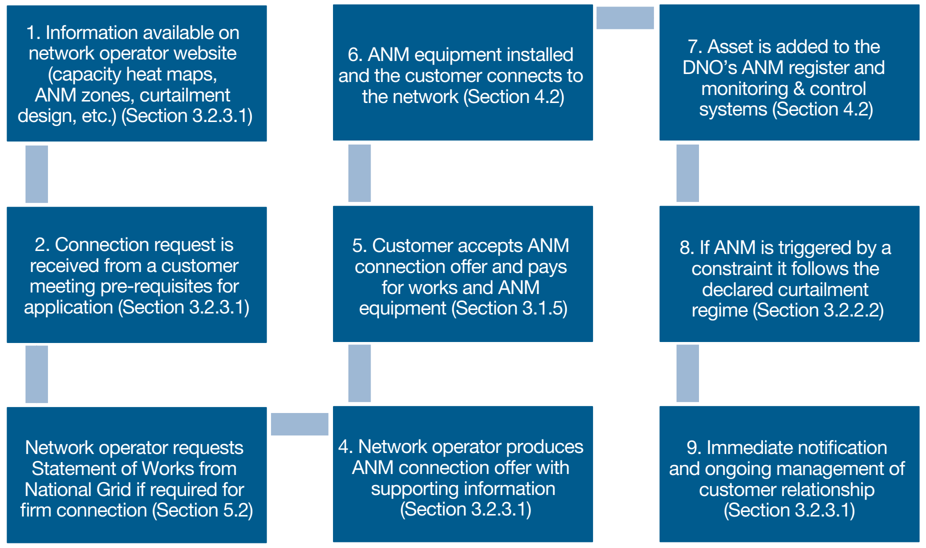


3.2.3 Connection and management process

3.2.3.1 Introduction

Having defined the overarching principles for offering ANM connections, a process for connecting individual assets needs to be followed. DNOs may introduce customers to its ANM offerings as part of the conventional process, but it is expected that DNOs will first offer a conventional connection within the statutory period, followed by an ANM connection offer in due course. A simplified version of the ANM connection process is given in Figure 4, which assumes that an ANM connection is requested and offered independent of the conventional connection process (whereas in practice a number of the steps will occur only once for both conventional and ANM connections)[20].

Figure 4 Simplified process for ANM connections



3.2.3.2 Customer Engagement

The existing connection process already requires the sharing of a large amount of information between the DNO and a customer, and an ongoing relationship whilst the connection is being planned and carried out. ANM connection offers need to include more information for customers, and a more involved ongoing relationship is required. The key points of customer engagement are listed below, along with some suggestions of good practice for how that engagement might occur.

Prior to a connection request (Step 1), the DNO may provide information about the network and the approach to offering connections in order to make the connection process easier. This is unlikely to be as detailed as the information contained within the connection offer, but information could include:

- > A description of the curtailment regime and associated assumptions used by the DNO
- > A general description of the network, including whether it is a peak exporter or importer, how constrained it is and what generator types are on, or planned to be on, the network
- > The above information could be converted into a tool (by the DNO or a 3rd party) to give curtailment estimates, allowing customers to understand the expectations and the risks around future curtailment

The goal here is to give customers a clear understanding of a complex system in plain English. This involves conveying to a customer what the system will look like and how it will operate. Ideally the customer will be helped to understand what will happen under various circumstances.

When **making a connection request (Step 2)** it is expected that customers will use the ENA's standard connection request form[21] as they would for a conventional connection request. The use of this common form by all DNOs (at least for straightforward connections) helps simplify the connection process, particularly for developers seeking to connect multiple assets across the country. It is not expected that additional information will be required to make an ANM offer, since the existing connection request form has the necessary level of detail.

At some stage in the process of making an ANM connection offer, the DNO will allocate some access to a given customer (e.g. position in the LIFO stack, or a proportion of a generation quota). There is a risk that customers will secure access for projects that take a long time to connect, or do not connect at all. A number of options exist to prevent a queue of such projects from developing. The DNO may require that a customer have secured planning permission, which would give some assurance that the project can be delivered. Alternatively, the DNO could allocate access based on the connection date (rather than the date of the connection application or offer). This would, however, impose a potentially large risk on the customer since the date of connection, and hence the terms of access, will not be known until connection occurs.

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[20] A more detailed description of the standard generator connection process can be found on the ENA website: http://www.energynetworks.org/modx/assets/files/electricity/engineering/distributed%20generation/DG%20Connection%20Guides/July%202014/G59%20Full%20June%202014%20v3_Updated.pdf

[21] http://www.energynetworks.org/modx/assets/files/electricity/engineering/distributed%20generation/Master_ENA_Generator_Application_Form_V2_April2011.doc

An **ANM connection offer is made (Step 4)**, assuming that ANM is, or can be, rolled out in the relevant area and that the asset meets the requirements discussed in Section 3.1. This is likely to follow some time after the conventional connection offer. In the meantime, the DNO may indicate whether the customer meets the requirements for an ANM connection offer (e.g. whether the zone is ANM-enabled, and whether the customer size and location is suitable). The ANM connection offer, or associated documentation, could give:

- A description of the curtailment regime, including the conditions under which future reinforcement would occur and details of any quota or curtailment threshold in place.
- Information or analysis relating to curtailment assessment. This could range from directing a customer to the Long Term Development Statement (LTDS), to providing a full curtailment assessment.
- If full curtailment assessments were provided by DNOs, the following caveats are expected to be included:

    – Any assessment is likely to be based on historic half-hourly information, so it should not be viewed as more than indicative of future curtailment
    – The assessment would be based on the current state of the network, and may not take account for changes to network topology or new connections, particularly if they exceed the current planning horizon
    – Whilst the DNO would endeavour to produce a curtailment assessment based on the best information available to it, it would not be liable for the outturn level of curtailment.

- An anonymised view of asset types currently on the network or that have requested a connection
- A description of how curtailment would work (including operational timescales, warning periods, required ramp rates)
- A description of the ways in which curtailment can be affected, along with a notification that the customer should use the data with caution and should conduct its own due diligence before accepting the connection offer

The ongoing relationship (Step 9) will be more involved under ANM connections. The ANM scheme itself will be in constant communication with the customer assets. Curtailment signals will be given, which may also be complemented by near-time communication with the customer to explain the reason for the curtailment. Customers will also need to be notified of any changes to the scheme.

3.2.3.3 Assessing, paying for, installing and operating the ANM scheme

The other steps in the connection process are covered in more detail elsewhere in this guide:

- Step 3 describes the Statement of Works (SoW) process agreed between National Grid and the DNOs. It is explored in more detail in Section 5.2 in the context of interactions between the transmission and distribution networks.
- Step 5 concerns the way in which a customer pays the DNO for ANM. This is part of a wider question surrounding the way in which ANM costs are recovered, including the site-specific costs and the central and upfront costs required to operate an ANM scheme. These issues were addressed in more detail in Section 3.1.5.
- Steps 6 and 7 concern the installation of ANM on a customer's site and the way it is integrated into the DNO's own systems. These technical considerations are discussed in Section 4.2.
- Step 8 concerns the way in which customers are curtailed when the network is constrained, which was discussed in Section 3.2.2.2.

Section 3.2.3 Good Practice: ANM connection process

- Guides and tools should ideally be made publicly available in a simple and clear format to help customers understand ANM connections
- ANM connection offers should follow conventional offers, but network operators may notify a customer that they are eligible upfront
- Information about the current and future network could be included in the connection offer as appropriate, with individual assets anonymised as necessary
- Once connected, network operators may give notification of curtailment, periods when the scheme is active, and any changes to the scheme as necessary
- Network operators should make clear to customers that they should carry out their own due diligence on the risk of curtailment, taking into account information provided by the network operator, but recognising the impact of unforeseen events (e.g. changes to network demand, technical failures, severe weather)

3.2.4 Variants for ANM connections on the transmission network

3.2.4.1 Introduction

Although ANM can be used on both distribution and transmission networks[22], the majority of the GB experience to date has been on the distribution networks, as can be seen from the case studies summarised in Appendix B. There is, however, one GB example to date of using ANM on the transmission network[23], which serves to illustrate some features of a transmission ANM connection offer, including:

- The conventional connection process and the rationale for offering ANM connections
- The behaviour of the ANM system and its interaction with existing control mechanisms
- How the use of ANM relates to any planned reinforcement

3.2.4.2 Conventional connections on the transmission network

The commercial arrangements for the connection of generation to the transmission system are fundamentally different from those on the distribution system. On the distribution network, a customer cannot connect until any necessary works are carried out to keep the network within its firm capacity (in the absence of an ANM scheme). By contrast, at the transmission level most generation is connected under the Connect & Manage regime, which allows customers to connect even if doing so would create or exacerbate a constraint on the wider network. National Grid distinguishes between two types of works, which are defined in the Connection and Use of System Code (CUSC) as follows:

- "'**Enabling Works**' are the minimum transmission reinforcement works which need to be completed before a generator can be connected to and given firm access to the transmission network (i.e. between the generator and the nearest suitable point on the network).
- '**Wider Works**' are the other transmission reinforcement works (i.e. not Enabling Works) associated with reinforcing the network to accommodate the new generating station and ensure compliance with the NETS SQSS[24]. The TSO would then manage the constraint by curtailing generation through the Balancing Mechanism (BM) until the necessary reinforcement has been carried out."[25]

In the case where a connection results in a need for Wider Works, whilst those works are ongoing the BM can be used to alleviate the constraint. Unlike Wider Works, however, Enabling Works need to be completed before a connection can be made. This can be an incentive on the customer to seek alternative arrangements in order to connect more quickly.

3.2.4.3 Offering an ANM connection on the transmission network

Where completion of Enabling Works is expected to significantly delay the connection date, a customer may benefit from an ANM connection while those works proceed. Figure 5 illustrates the network configuration under which this could work. In this example, ANM could be used as follows:

- Generator G1 is an existing transmission connected generator
- Generator G2 wishes to connect to the network behind transformer T1
- The maximum export capacity (C) of G1 and G2 combined exceed the capacity of T1, so G2 cannot connect until T1 is reinforced (on the assumption that reinforcing T1 constitutes Enabling Works)
- Rather than waiting for T1 to be reinforced before connecting, G2 can connect under an ANM connection, using any spare capacity not being utilised by G1
- The ANM system monitors the local network, measuring the power flowing through T1
- The ANM curtails G2 as required to keep the power flow through T1 at or below its firm capacity

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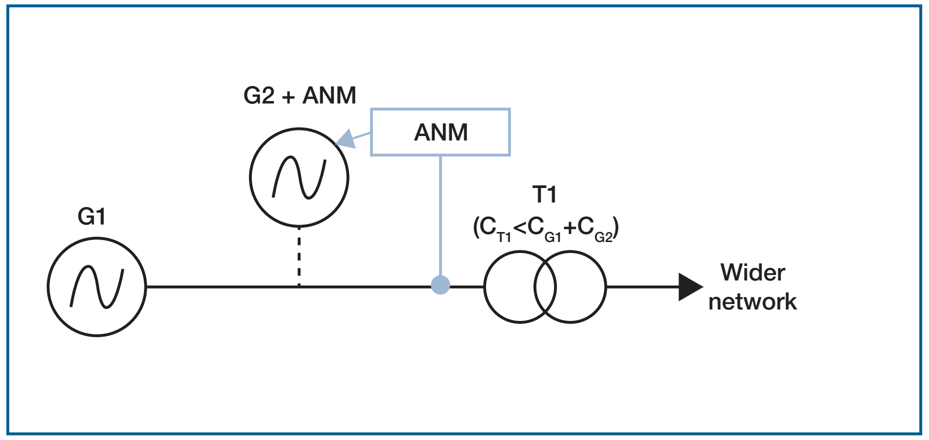
[22] "Distribution" includes voltages from 6.6 kV up to 132 kV (132 kV is a distribution voltage in England & Wales), whereas "transmission" refers to voltages from 132 kV up to 400 kV (132 kV is a transmission voltage in Scotland)

[23] Lochluichart Wind Farm

[24] National Electricity Transmission System Security and Quality Supply Standards

[25] http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=33847

Figure 5 Illustration of a transmission-level ANM connection



It should be noted that a similar behaviour could be achieved by using an intertrip scheme, but rather than offering gradual curtailment this would result in sudden and total loss of export capability, and a lower average load factor for the customer.

Restricting the use of ANM to radial networks, as is the case in Lochluichart, has two advantages:

1. The ANM system can make decisions on the basis of monitoring a single transmission asset on the network (e.g. power flows on a single overhead line), without needing to consider the state of the wider network
2. The effect of the ANM action on the network as a whole is predictable, with no need for complicated and time-consuming modelling

On more complicated meshed transmission networks, the effect of ANM actions are thought to be too complex and unpredictable to implement safely. Understanding the behaviour at any given time would require power flow analysis, which is incompatible with the near-instantaneous timescales at which ANM operates. It may also conflict with the wider system operation performed in the TSO control room. It is recommended, therefore, that, at least with the technology in its current state, the use of transmission-connected ANM be limited to radial networks[26].

3.2.4.4 Whether ANM is an enduring solution on the transmission network

As described above, the primary use for ANM on the transmission network is to allow a customer to connect whilst Enabling Works are still being undertaken. The implication, therefore, is that ANM will be a temporary measure, which will become unnecessary once reinforcement has occurred.

However, there may be instances in which Enabling Works are prohibitively expensive, or cannot meet local planning requirements (for example because of their environmental impact). In such cases, it may be that ANM becomes the enduring solution, with the customer facing periodic curtailment indefinitely. Any planned reinforcement will be carried out on the basis of a Cost Benefit Analysis (CBA), which should identify cases where enduring ANM is the preferred solution.

Section 3.2.4
Good Practice: Transmission ANM connections

- ANM should be considered where Enabling Works are seen to be too costly or take too long
- ANM should only be used on radial elements of the network, where its impact on network operation can be easily understood
- Although it is currently expected that ANM connections on the transmission network will be used as a temporary measure, its use as an enduring solution could be considered if justified by a Cost Benefit Analysis
- Where possible, the parties bearing the cost of curtailment should be the same as the parties avoiding the cost of reinforcement, thereby ensuring the correct economic incentives are in place

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[26] Although it should be noted that even for a radial network, there are potential issues with ANM undermining BM actions, as is discussed in more detail in Section 5.2.

3.2.5 Variants for connecting demand under ANM connection agreements

The previous sections focused on the connection to the network of generation under ANM connection agreements. Although it has been less explored to date, it should also be possible to connect some demand customers under an ANM connection agreement. Because there has been little experience of doing this, this section gives a limited assessment of some of the key differences that might be expected when using ANM connection agreements to connect demand rather than generation.

In most aspects of the ANM scheme the curtailment of generation on an export-constrained network is analogous with curtailing demand on an import-constrained network. In both cases, the ANM scheme would curtail ANM-connected assets when the network's firm capacity would otherwise have been exceeded. The key difference between connecting generation and connecting demand, therefore, comes from the nature of the customers themselves:

- For a generation owner, curtailment of output translates into a relatively predictable per-MWh revenue loss. In the case of 'true' DSR, which is to say actual reduction in consumption during peak periods, any loss of service may be disproportionately expensive (e.g. the loss of power to a data centre is worth considerably more than the value of the power itself). Because curtailment under an ANM connection agreement is mandatory (in contrast with the commercial curtailment schemes discussed in Section 3.3), this may limit the range of demand customers willing to accept ANM connections.
- The majority of demand sites connecting to a network will involve multiple electricity meters, representing a large number of individual consumers (e.g. new business parks or residential developments). Not only would these parties need to agree to the ANM connection, but there would need to be a physical mechanism by which these individuals' demand could be curtailed.
- Generation customers are, in general, more knowledgeable about the energy market and may be more comfortable with the risks associated with ANM connections.

Given these restrictions, three categories of demand may be amenable to ANM connections:

- **Net demand sites with behind-the-meter generation**: Any generation behind the meter, such as backup diesel generators, may be used to reduce the net demand at a particular site. Such assets could be controlled automatically, with no impact on actual consumption patterns.
- **Single large consumers (typically Industrial & Commercial), or sources of demand that are controlled by a single operator**: These may be more suitable for ANM connections. Examples might include cold storage units, swimming pools heated with electric heat pumps or, in the future, commercial fleets of electric vehicles with dynamic charging systems put in place that allow the timing and rate of charging to be varied centrally.
- **Customers with substantial use of smart technologies**: As more appliances can be remotely controlled, new developments could agree to be partially curtailed by disabling specific pieces of equipment for a period of time. For example, a new residential block with storage heaters, immersion heaters, air conditioning or heat pumps could be curtailed for a period without adversely affecting living standards. A critical mass of smart appliances would be required to ensure that curtailment could be predictable and reliable.

3.3
Using existing customers to maximise network utilisation

3.3.1 Introduction

A DNO can incentivise existing customers to alter their generation or consumption during periods of constraint in order to defer or reduce the need for network reinforcement. Although new connections are a major driver of network expansion, which can be alleviated through the use of ANM connection offers as described in Section 3.2, there are a number of other situations where network reinforcement might be required:

- Demand growth on an import-constrained network resulting from changing consumption patterns or new demand on existing connections (such as an expansion in residential Electric Vehicles)
- A reduction in net demand on an export-constrained network (for example, as a result of efficiency measures, the closure of large demand customers, or an increasing penetration of small-scale generation)
- Connections at a lower voltage level driving constraints at higher voltage levels, the cost of which cannot be recovered from the connecting customers under the CCCM.

The need for reinforcement can be reduced or deferred by accessing flexibility from existing network customers, enabled by ANM.

In the majority of cases, the current approach taken by DNOs is to undertake "general reinforcement". This planned capex is recovered through DUoS charges, as governed by price control mechanisms. As part of these price controls there is an efficiency incentive for DNOs to find alternatives to conventional reinforcement where it is cost-effective to do so, thus providing an impetus to explore options using ANM[27].

The action that a DNO might seek to take depends on the nature of the constraint[28] on the network and the type of customer offering it flexibility, as summarised in Table 6. In each case the DNO may also need to consider the impact on transmission network constraints and the balancing of the overall system.

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[27] https://www.ofgem.gov.uk/ofgem-publications/47068/riioed1decoutputsincentives.pdf

[28] It is assumed that ANM will be used to manage thermal constraints only, but the possibility of managing other constraints (voltage, reactive power, fault level) are considered in Section 6.

Table 6 DNO actions under different constraint and customer types

		Customer type			
		Demand		Generation	
Network constraint	Import-constrained	↓ Demand	DSR involves reducing a customer's net demand, either by reducing (or time shifting) true consumption or increasing behind-the-meter supply (e.g. backup generation)	↑ Generation	Similar to DSR in its effect on the network, but the range of potential customers, commercial terms and response characteristics may be different
	Export-constrained	↑ Demand	DSR can include increasing consumption. The range of customers that are able and willing to increase rather than reduce consumption may be different, but otherwise the commercial arrangements are likely to be similar	↓ Generation	Operationally this would be very similar to the ANM connections described in Section 3.2, but in this case curtailment would be on the basis of a new commercial agreement, rather than as a requirement for connection

In the trials done to date, flexibility has mostly been provided by reducing the consumption of electricity customers on import-constrained networks through the use of DSR. For this reason, the remainder of this section will use this example to explore this application.

3.3.2 Using DSR to defer or avoid general reinforcement, and the role of ANM

Conventional reinforcement is used by DNOs when the peak demand is expected to exceed a network's firm capacity.[29] Instead of increasing the firm capacity in this way, an alternative approach is to use DSR to reduce the expected peak demand. In principle, DSR can offer the same security of supply that would have been delivered through reinforcement.

DSR may allow reinforcement to be deferred, but in some cases it may allow it to be avoided altogether. Given that conventional reinforcement needs to occur before a network exceeds its capacity, the decision to reinforce will be based on demand growth forecasts. Such forecasts are inherently uncertain, and in some cases the expected net demand growth may not transpire (e.g. micro-generation or energy efficiency take-up may exceed expectations or high-demand businesses may close). In such cases, conventional reinforcement that would otherwise be 'stranded' can be deferred indefinitely by using DSR. Hence, DSR can create optionality, which is of value to DNOs and to consumers.

It is possible to make use of customer flexibility without a formal commercial arrangement being in place. This was demonstrated, for example, with Electricity North West's Customer Load Active System Services (CLASS) project, which showed that by operating at the lower end of the voltage tolerances, a temporary reduction in demand could be achieved.

In most cases, however, the DSR is delivered via a commercial arrangement with flexible customers. The DNO calls for a customer to reduce its net demand when flows on the network exceed its firm capacity. For agreeing to this arrangement customers would typically receive:

- **Availability payments** in return for being willing and able to provide DSR, and/or;
- **Utilisation payments** to be made on the occasions where customers are called on to reduce their net consumption.

In addition, the commercial agreements may specify limits on the number or duration of DSR actions that a DNO is allowed to take.

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[29] For the purposes of this section it is assumed that ANM is used on a pre-fault basis, which is consistent with its application to date.

These actions can be taken without a fully-fledged ANM system, but integrating these actions into an ANM system has the potential to improve the contribution that these customers can make to network security, because their response to a DSR signal is expected to be more reliable[30]. For the remainder of this report, the terms "Conventional DSR" and "ANM-enhanced DSR" are used to differentiate between these two concepts.

For any given planned reinforcement, there may be a viable option to implement DSR instead. Table 7 summarises the questions that a network planner may need to answer in order to make that determination.

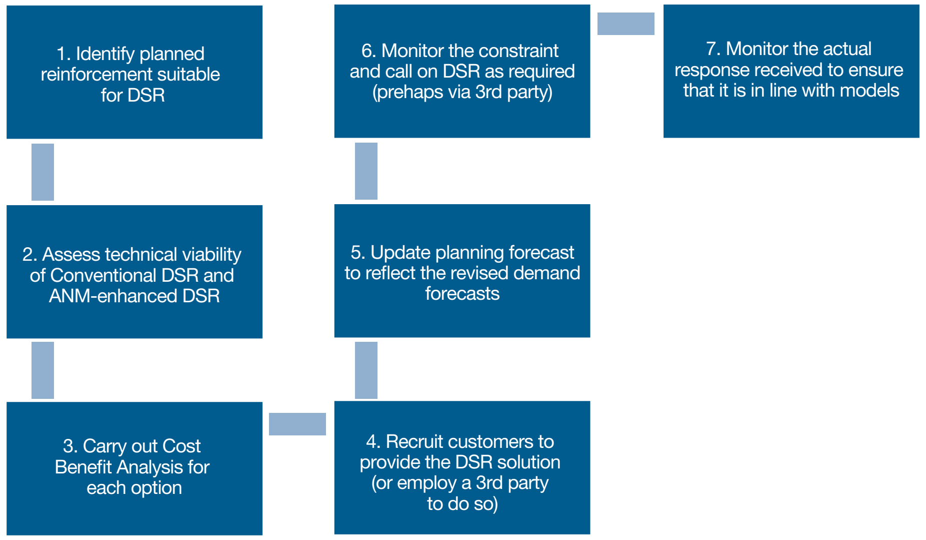
3.3.3 Process for identifying alternatives to network reinforcement

In order to answer the questions detailed in Table 7, some changes to the existing network planning process may be required. Each DNO will have its own existing process for network planning, and may be integrating ANM into its business processes in different ways. This section, therefore, gives a high level and generic view of the process a DNO may choose to follow in order to identify and assess potential opportunities to use DSR, and to determine whether it makes sense for that DSR to be enhanced with ANM, as is summarised in Figure 6.

Table 7 Checklist for identifying suitable DSR opportunities

Implement conventional DSR?	> Is a reinforcement planned at a given network location?
	> Is DSR a viable option? Are enough of the right customers available to provide DSR? Would peak reduction actually allow reinforcement deferral in practice?
	> Is DSR a cost-effective solution when compared with the conventional alternatives, such as reinforcement and temporary generation?
	> Can the required customers be recruited successfully?
Upgrade to ANM-enhanced DSR?	> Is the network zone ANM-enabled already? How much would it cost to make the zone ANM-enabled?
	> How much more reinforcement deferral does ANM allow?
	> Is the increased deferral worth the additional cost of using ANM?

Figure 6 Simplified process for deciding whether to use DSR



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[30] By allowing for more robust and rapid response ANM could also mean that DSR could be used for a wider range of applications such as real-time post-fault response, network protection and fault level management. These more advanced applications are considered further in Section 6.

1. **Identify planned reinforcement suitable for DSR**
   In principle, every planned reinforcement may be an opportunity to use DSR. Testing each of these individually may be a time-consuming task so if the DNO chooses to carry out this activity in-house (as opposed to via third parties, as discussed in Section 3.3.4) processes will need to allow the efficient identification of a shortlist of suitable candidates for DSR.

   The process of identifying suitable DSR opportunities requires the bringing together of information from different business units. This would be made more efficient if a unified database could be created bringing together the relevant information from across the organisation. This could then be converted into a tool to help to query this database and identify sites most likely to benefit from DSR. Some high level specifications for such a tool are given in Table 8.

2. **Assess technical viability of Conventional DSR and ANM-enhanced DSR**
   Having identified plausible DSR candidate sites a full technical assessment of both Conventional and ANM-enhanced DSR therefore would need to be carried out. This assessment may ask whether, given the constraint and the asset mix, reinforcement deferral could actually be achieved. The deferral estimate should not be over-idealised, rather taking into consideration the interactions between one reinforcement and other planned reinforcements on the network, and in particular ensuring that the reinforcement is not required as part of a larger scheme.

Table 8 Database/tool for shortlisting DSR candidates

About the constraint	> Date of planned reinforcements > Interactions with other planned reinforcement schemes > Cost of the planned reinforcement > Shape of the profile driving the constraint (e.g. flat vs peaky) > Rate of growth of net generation/demand before and after the planned reinforcement
About the customers	> Number and sizes of customers by geographical location (e.g. postcode) or ideally by topological location (i.e. ability to alleviate constraint)[31] > Information about customer type (e.g. demand, storage or generator, response times, whether "true" DSR or behind-the-meter generation) > Whether the network is ANM-enabled > Estimate of generation/demand change under DSR, and a model of how customers would respond individually, and viewed as a portfolio

The deferral estimate would account for the possibility that a DSR provider does not respond. This can be expressed as an "F-factor" for an asset or portfolio of assets. The F-Factor indicates, for a given level of declared DSR, how much can be assumed to contribute to security of supply.[32] There is no agreed standard for how F-factors should be calculated, although this is being addressed as part of the Engineering Recommendation P2 (ERP2) review. Work carried out by UK Power Networks under LCL[33] suggests the following:

- Different DSR types will have different F-factors (e.g. actual demand reduction will not have the same reliability as DSR via a behind-the-meter diesel generator)
- The more DSR providers there are, the higher the average F-factor of each provider as, through diversification, the aggregate response of multiple providers is more predictable than a small number
- There may be additional benefit of having a diverse portfolio of DSR types, as this decreases the risk of a common mode failure under which multiple providers would be unavailable for the same reason

Although F-factors with ANM have not been calculated, the expectation is that such schemes are more reliable (in the sense that the request for demand reduction is more likely to translate into actual demand reduction) and less prone to unexpected fluctuations. As a result, the F-factor that can be assumed would be likely to increase considerably. This is perhaps the primary benefit for opting for ANM-enhanced DSR over Conventional DSR.

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[31] This information may not be held by the network operator for all customers. It may become more readily available with the widespread deployment of advanced and smart meters, but would require payment by the network operator.

[32] For example, an asset may be contracted to provide 10kW of DSR, but have an F-factor of 50%, in which case only a 5kW reduction can be assumed for planning purposes.

[33] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/Project-Documents/LCL%20Learning%20Report%20-%20A4%20-%20Industrial%20and%20Commercial%20Demand%20Side%20Response%20for%20outage%20management%20and%20as%20an%20alternative%20to%20network%20reinforcement.pdf

3. **Carry out Cost Benefit Analysis for each option**
   Assuming that DSR is technically feasible, a CBA would need to be carried out, considering the impact on both capex and operating expenditure (opex). The Net Present Value (NPV) of the relative future costs and benefits of each option would be calculated and, provided there are not any other considerations (e.g. technical or regulatory), the option with the highest NPV would be chosen. The relevant costs and benefits to consider are:

- The value of the expected reinforcement deferral that DSR would deliver
- The expected cost of operating the DSR scheme (based on estimates of availability and utilisation payments)
- The additional value of using ANM-enhanced DSR arising from higher and more robust DSR response
- The additional cost (both capex and opex) of using ANM-enhanced DSR (which may depend on whether the network zone is already ANM-enabled)
- The chance that conventional reinforcement becomes unnecessary, resulting in stranded assets, and the 'real option value'[34] DSR therefore brings by allowing the DNO to delay the investment decision

4. **Recruit assets to provide the DSR solution**
   Having decided on an optimal DSR strategy, the DNO then needs to recruit customers to provide the DSR solution. This could be done in-house, perhaps by a dedicated DSR manager. Alternatively, as discussed in Section 3.3.4, a 3rd party could be used.

   The number of DSR providers required will be a function of whether ANM is to be used. Customers will be contracted for a given period, which may be shorter than the expected period of reinforcement deferral. There may be a need therefore to review and renew these contracts periodically. It may also be necessary to tie customers in for the duration of the reinforcement deferral (perhaps with index-linked fees) to ensure that costs do not escalate.

5. **Update planning forecast to reflect the revised demand forecasts**
   Once it has been decided to implement a DSR scheme, the DNO's planning forecasts need to be updated accordingly. This could be revised as the DSR recruitment process is underway to reflect the latest best view of the deferral that will be achieved.

6. **Monitor the constraint and call on DSR as required**
   Once operational, the DNO or ANM system will need to monitor the constraint and call on DSR providers as required:

- Under ANM, this would be carried out automatically in response to a measured network condition (e.g. a thermal load reaching a predefined limit)
- For the Conventional DSR, the monitoring and control would be done via the DNO's control room, and would be a more manual process

Some consideration would therefore need to be made of the interaction between the ANM-enhanced DSR and the Conventional DSR to ensure that the order in which DSR was applied resulted in the correct level of response, and ideally that the least-cost option would be chosen.

Whether ANM-enhanced or Conventional DSR, the enacting of DSR would need to take into account any commercial constraints built into their contracts such as exclusion periods, limits on the number of DSR events in a given period, limits on the duration of a single DSR event, or minimum time periods between DSR events. The need to trade off these multiple constraints introduces a degree of complexity for an ANM system, and a risk that there could be a set of unexpected network conditions under which it fails to perform correctly.

7. **Monitor the actual response received to ensure that it is in line with models**
   The DNO must monitor the actual response received from the DSR providers to ensure that it is in line with modelling expectations and contractual obligations.

3.3.4 Using third parties

The process above assumes that the DNO will identify and mange DSR opportunities in-house. However, it may be able to use third party providers, such as aggregators, for some of the steps. There are degrees of involvement that may be appropriate:

- One option is to use aggregators to help with the identification and recruitment of potential DSR providers. This may be more efficient and less costly than the DNOs identifying and recruiting customers themselves, particularly if there is no existing function or skill set in place to perform this role.
- Aggregators could also manage the ongoing relationship with the DSR providers, acting as an intermediary with the DNO. The DNO would still choose which DSR customers to call upon, and would be responsible for ensuring that sufficient customer flexibility existed to mitigate the constraint.

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[34] A real option gives the holder the right, but not the obligation, to take an action in the future. In this case, DSR converts the DNO's obligation to reinforce into a right, which it may or may not enact depending on future load growth. This additional optionality is of value to the DNO.

- DNOs could use the full aggregation service, with aggregators enacting the required DSR on behalf of the DNO.[35] The aggregator would have responsibility for delivering the response required to keep the network within its firm limits. From the perspective of the DNO, the aggregator itself would be the DSR provider in this model. It should be noted that, unless the aggregator has its own ANM system, this setup may only be feasible for Conventional DSR (with the lower F-factors that this would provide).

3.3.5 Variant using ANM to restore customers following a fault

The above examples assume that customers will need to be curtailed on a pre-fault basis to prevent the network from exceeding its firm capacity. It is also possible to increase the utilisation of the network by using ANM to manage the way in which customers are reconnected following a fault, as was trialled in the Electricity North West C2C project.

Under a conventional connection, after a fault a customer's supply is usually restored within one hour. On a C2C contract a customer's "essential" supply is restored as soon as possible along with non-C2C customers, but the restoration of "non-essential" power is delayed for a pre-arranged period of time. For this, existing customers would receive a fee (also note that C2C is available to newly-connecting customers, who are offered lower connection charges). Customers are only affected on the rare occasions when a fault occurs on the network.

The existing network is enhanced to provide the active management functionality required to operate the system within these commercial arrangements. Remote control is installed at the Normally Open Point (NOP) between two adjacent radial high voltage (HV) circuits which are closed to form a closed ring and so increase available latent capacity. At intermediate points on both circuits additional remote control are installed to enable flexible rapid re-supply of customers following an outage. This decreases the amount of time that non-managed customers are off supply due to a fault.

This approach allows more of the network capacity to be utilised, thereby reducing the need for reinforcement. The fact that action is only taken following a fault, and that essential power is prioritised in the restoration process minimises the impact on consumers.

Section 3.3
Good Practice: Deferring general reinforcement

- A network operator's Planning team should be able to carry out a quick assessment of planned reinforcements to assess their possible suitability for deferral using DSR, perhaps with a unified database or a tool
- There should be regular communication between the Planning, Connections and, where required, a dedicated DSR function to identify and assess plausible candidate DSR sites (if not provided by a 3rd party)
- A technical feasibility assessment should be carried out, taking into consideration the nature of the constraint, the number and types of asset behind that constraint, the DSR each might be able to deliver and the contribution that this could make to security of supply
- An appropriate economic case should be made each time DSR is considered
- Some form of regular audit may be required to ensure that the achieved DSR is delivering the expected response at the intended cost, and that the business case for DSR remains valid
- ANM can also be used following a fault to manage the restoration of customer supply, allowing more of the latent network capacity to be used with minimal impact on consumers

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[35] The DSR providers employed by the aggregator may also be used to offer other system services (such as TRIAD avoidance or Short Term Operating Reserve) provided the hierarchy of actions is well defined

Deploying an ANM scheme

4

4.1
Introduction

This section concerns the way in which network operators may choose to design an ANM scheme and integrate its operation into their businesses. Section 4.2 addresses technical considerations such as ANM system architecture, functional specification, control room integration and safety. Section 4.3 addresses the commercial and operational changes that may be required in order to embed ANM as Business as Usual including operating models and the training that may be required.

4.2
Technical considerations

The technical integration of ANM involves physically embedding a scheme into a DNO's existing electrical and communication infrastructures, as well as into its network operations and management practices.

The system architecture of an ANM scheme will define to a large extent how it is integrated with existing network systems, and the more detailed functionality requirements inform hardware, software, SCADA (Supervisory Control and Data Acquisition) and communications specifications. Control room visibility and network safety considerations are critical to the operation and management of networks and will determine the interfacing requirements.

This section summarises good practice for the technical integration of ANM and explores how different scheme characteristics influence how this is best achieved.

4.2.1 System Architecture

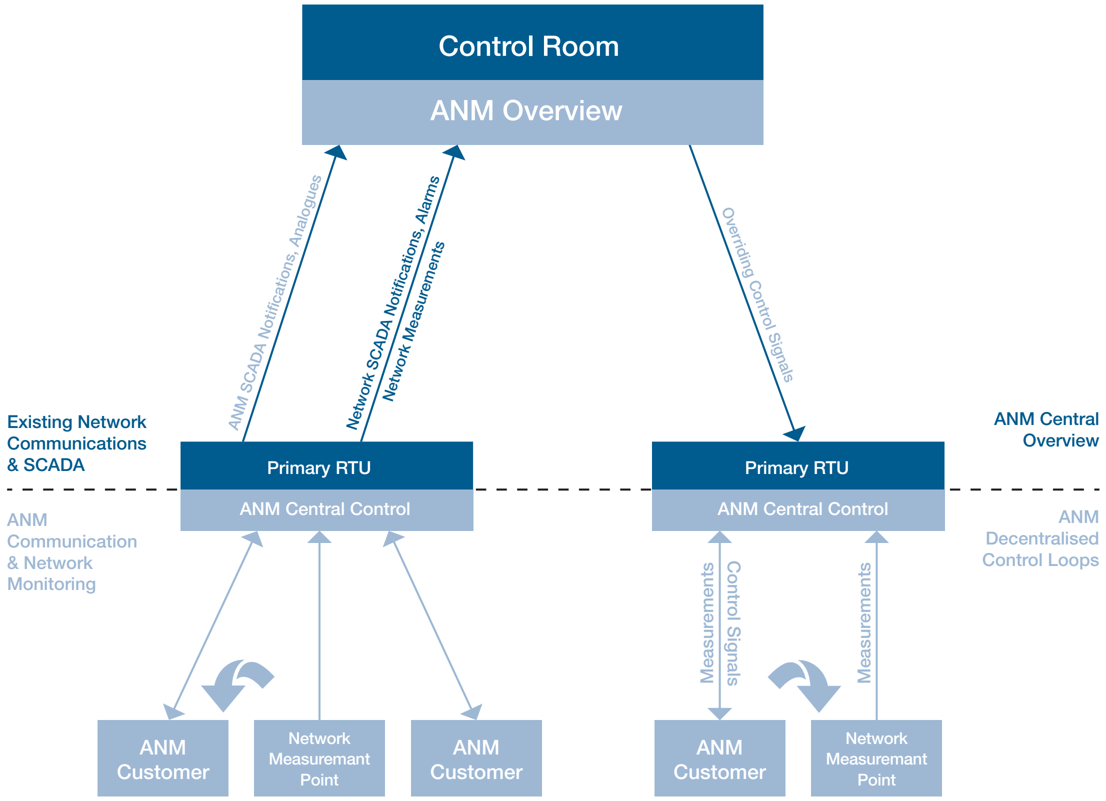
4.2.1.1 Introduction

The technical architecture of an ANM scheme can be largely defined as either decentralised or centralised. The distinction between the two is found in the integration method, with remote devices performing algorithms in decentralised schemes and centralised schemes being more embedded within central network control. The characteristics of both types of architecture are described in the following sections with good practice noted for optimum architecture design.

4.2.1.2 Decentralised Architecture

An ANM scheme is considered to be decentralised when it employs programmable devices, such as Programmable Logic Controllers (PLCs) or relays, and these are located out on the network within Remote Terminal Units (RTUs) and generation plant control systems. These remote distributed devices monitor and/or control customer and network assets by receiving measured data, executing algorithms and issuing appropriate control signals in a decentralised manner. In some cases, these devices may need to interface with other devices at different remote locations in order to obtain network measurements or indications. The local control is carried out automatically and autonomously, but notifications and key metrics from analogue measurements via SCADA ensure the Network Management System (NMS) is updated upon any actions and status changes. The NMS can also be used to execute controls over the ANM scheme if necessary e.g. set-point changes or enabling/disabling the scheme itself, and this is discussed in more detail in the following sections. Figure 7 provides an illustration of a typical decentralised ANM architecture.

Figure 7 Decentralised ANM Scheme Architecture



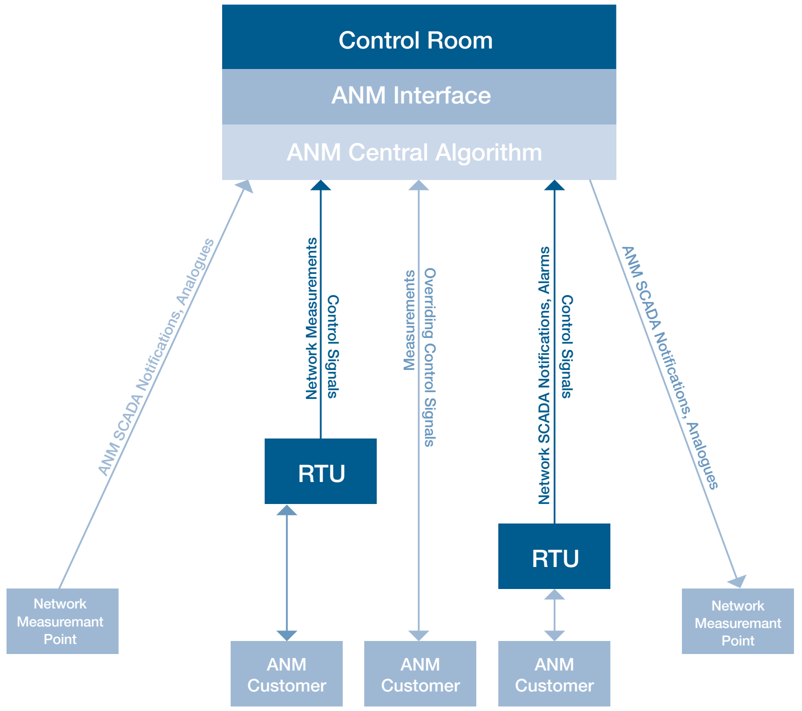
4.2.1.3 Centralised Architecture

A centralised ANM scheme is characterised by the coordination of the ANM actions from a central algorithm. The control room NMS will receive input signals from the SCADA system with which the scheme is integrated, and the ANM algorithm then processes these inputs to determine any required actions and issues appropriate control signals to the ANM-connected customer assets via the SCADA system. Figure 8 illustrates a centralised ANM scheme architecture.

Some commercial NMSs in use by UK DNOs enable the coding of user defined logic or scripts for ANM schemes.

An alternative centralised architecture would be a stand-alone ANM server, located in the control room and functioning in parallel with the NMS with key data such as network models shared between the two systems. Some commercially available ANM systems are designed to function as stand-alone systems in this manner.

Figure 8 Centralised ANM Scheme Architecture



4.2.1.4 ANM Architecture Characteristics

Table 9, describes the various characteristics of decentralised and centralised ANM architectures based on scheme features.

Table 9 ANM System Architecture Characteristics

	Decentralised	Centralised
Scheme location	Well suited to remote locations where communications with central network control may not be reliable and/or robust enough.	Locations served well by existing SCADA and also in areas where it is not ideal to install a software-based scheme out at the generator (e.g. protocol incompatibility or harsh environmental conditions).
Constraint type	More suitable for localised constraints (e.g. on a radial circuit) although a decentralised ANM "zone" could address wider grid constraints.	A centralised approach is well suited to management of a wider grid constraint due to increased visibility and controllability requirements.
Response time	A decentralised architecture can be specified to provide a response that is more rapid than the SCADA system, if required.	The required response time should be consistent with that provided by the SCADA system.
Controllability & Visibility	Can be lower visibility and controllability if communications with central network control is not so reliable and/or robust (see Scheme Location).	Good visibility and controllability of the scheme.
Reliability	Multiple hardware devices mean more likely for one or more to be in fault state at any one time, although less chance for single catastrophic failure.	Dual SCADA communications structure provides redundancy. However, the NMS is a single point of failure (although failure is highly unlikely).
Cost	"Plug and play" on existing hardware reduces costs but there is a greater number of hardware devices (although some of these may be customer owned).	Costs to fully integrate within the NMS (or stand-alone equivalent).
Security	Easily segregated from NMS so connection of customer assets and control systems should not affect NMS security.	Where existing SCADA is used, integration of customer assets and control systems into the NMS is required so there can be security challenges. However, the security of a single ANM solution interfacing directly with multiple ANM customers can be more easily managed and controlled centrally behind the corporate firewall compared to decentralised management of devices in remote multiple locations.

The most effective approach for any particular scheme will be governed by the considerations above as well as specific network and customer characteristics. Most operational ANM schemes are what are considered to be "hybrid" systems. These combine the characteristics of centralised and decentralised architectures by having hardware devices deployed at remote network and customer locations, but a central server coordinating the overall operation of the scheme.

Section 4.2.1
Good Practice: System Architecture

> A centralised architecture is preferred to manage wider network constraints
> A decentralised architecture is favoured where response times more rapid than a SCADA (Supervisory Control and Data Acquisition) system's capabilities are required
> A "hybrid" approach can improve overall ANM scheme reliability by having improved communications redundancy over decentralised architectures and removing the "single point of failure" feature characteristic of centralised architectures

4.2.2 Functional Specification

4.2.2.1 Introduction

It is the responsibility of the DNO to provide a set of functional specifications to which an ANM scheme must adhere in order to perform as required. These encapsulate key features that allow the ANM scheme to integrate as necessary with the existing network systems. Generic functional specifications have been developed by a number of DNOs, evolving from experiences with innovation projects, to enable cost-effective procurement when ANM is more widely deployed. The functional specifications set out by DNOs fall into the following four main categories:

- System Configuration and Algorithms
- Measurements and Data Exchange
- Communications and Interfacing
- Forecasting

These categories are explored in more detail in the subsequent sections to present good practice for the content of functional specifications.

4.2.2.2 System Configuration and Algorithms

Generally, there is commonality with regard to the specifications for system configuration and algorithms of both decentralised and centralised ANM schemes. Algorithm requirements include:

- **Real-time analysis of network parameters in relation to limits**
  The ability to collect and analyse network parameters and assess these in relation to any limits imposed is central to ANM scheme performance. The network parameters likely to be under scrutiny for the purposes of ANM include power (MW, MVAr, MVA), current and voltage. The analysis can be carried out for a variety of objectives, such as generation output in respect of a set-point, voltage profile in respect of statutory limits or power flow along a circuit in respect of thermal operational constraints (i.e. N-1 plant ratings).

- **Capability to perform control and parameter management actions**
  In the event that a limit has been exceeded, an ANM scheme must have the capability to take escalating action to alleviate the issue. This could be achieved by such measures as generator curtailment, set-point control, or the opening of a circuit breaker.

  ANM algorithm interaction with existing control and protection systems should be carefully considered to ensure that neither is compromised.

- **Implement principles of access**
  Where an ANM scheme has customers connected to it (generation or demand), its successful commercial operation relies upon it implementing control actions over these customers in the correct order according to the principles of access in place. These will be agreed upon prior to ANM scheme deployment such that the algorithm is pre-programmed. Additional customers connecting to a scheme will require an update of the configuration.

- **Ability to adapt to changes in system conditions**
  Planned or unplanned outages result in a change in system conditions (e.g. loss of a circuit or a transformer). In either case, an ANM algorithm must be able to reconfigure accordingly (where different network asset ratings may apply depending on the nature of the outage) such that it can continue operating and connected customers are minimally affected. Control oscillations (i.e. a generator is curtailed then released in a constant cycle) should be minimised through appropriate setting of control deadbands.

- **Detect and take action in instances of non-response or non-compliance**
  An ANM algorithm will be programmed with a feedback function to ensure that in cases where a customer or piece of equipment does not respond sufficiently to a control signal, the scheme can detect it within a specified time scale and apply failsafe modes (described next).

- **Apply failsafe methods**
  The application of failsafe methods is imperative to an ANM scheme and these will be programmed into the ANM algorithm to manage scheme behaviour and customer involvement for a range of eventualities. Failsafe methods can encompass, but are not limited to, the following, depending on the nature of the ANM scheme and the failure mode:

  - Revert to static limits upon the loss of dynamic rating information;
  - Maintain and hold customer output for a pre-determined period;
  - Disconnect individual or multiple customers after a period of non-response or non-compliance;
  - Disconnect the ANM scheme if the algorithm cannot reconfigure to new system conditions;
  - Disconnect the scheme in emergency conditions (when outside the ANM scheme operational envelope);
  - Disconnect the scheme (or revert to back up facilities) upon the loss of critical hardware, communications or SCADA; and
  - Manual override facilities for the control room.

- **Performance Criteria**
  In addition to specifications for the ANM control algorithm(s), a DNO may also choose to stipulate certain criteria for the performance requirements within which the ANM scheme and its devices should be capable of operating. Some examples of performance criteria that may be specified are:

  - Minimum technical specification of hardware devices
  - Input and output signal capability
  - Processing capacity
  - Data polling/resolution
  - Ability to operate in hostile electrical environments
  - Compatibility of ANM components with existing SCADA system
  - Protection interaction requirements
  - Communication protocols
  - Equipment reliability figures and/or targets
  - Interfacing with ANM-connected assets
  - Interfacing with the control room
  - Interfacing with the transmission network.

4.2.2.3 Measurements and Data Exchange

The performance criteria described in Section 4.2.2.2 previously play a significant role in the measurement and data exchange activities of an ANM scheme which include:

- Measurement and notification of DNO network parameters
- Measurement and notification of ANM customer network parameters
- Issuing of control signals and set-points

Data exchange takes place both internally (i.e. within the ANM scheme) and externally between the ANM scheme and the control room. The associated specifications set out by the DNOs include:

- **Data Resolution and Polling**
  Where existing SCADA is used, the real-time resolution of data polling, analysis and control signals of an ANM scheme should be consistent with the resolution of the existing network SCADA and management system and in line with any performance criteria (e.g. rapid response). In general, the standard poll rate time for SCADA is in the region of 600ms depending on the SCADA protocols in use (SCADA protocols are explored in Section 4.2.2.4). Where there is a conflict with ANM performance criteria particularly in terms of polling then a more decentralised approach may be more appropriate.

- **Data Processing**
  In decentralised ANM schemes, processing of measurements and data will take place locally on remote hardware devices. It is necessary to ensure that these devices have adequate processing power available to receive inputs, make decisions based on these and then issue control signals accordingly.

- **Interfacing Capabilities**
  Each of the components of an ANM scheme will be required to interface with at least one of the following:

  - Other ANM-connected assets
  - DNO network assets (e.g. RTUs)
  - The control room NMS
  - DNO data historian
  - The transmission system

  Interfacing must therefore take place, which allows the ANM scheme and DNO assets to communicate.

- **Data Exchange with the Control Room**
  Data exchange with the control room will encompass:

  - Real-time analogues and ANM scheme metrics
  - SCADA notifications prompted by a change in ANM scheme status or conditions
  - Issuing of control signals

Additional Considerations

The costs associated with purchasing and installing new SCADA and communications assets means that it is considered good practice to leverage existing communications assets where possible. However, the level of curtailment is highly dependent on communication equipment resiliency and so it may not always be possible to make use of the existing system.

Where existing communications can be used, the resolution requirements of ANM measurements and data polling may be higher than that of the existing polling rates used by the SCADA system. Modifications such as increasing the polling rate would then be required to ensure the requirements can be met. In such cases, the communications can prove to be a bottleneck. However, the improvement of communications for ANM purposes may still be cheaper than traditional reinforcement works.

Another prominent issue associated with SCADA is latency; a feature which is inherent with most of the SCADA networks used by DNOs today and which makes it difficult to assess some of the more dynamic aspects of the system. The effects of latency, and SCADA reliability overall, on ANM operations vary depending on the performance requirements and the response times required, with schemes requiring rapid responses (e.g. for frequency control at the transmission system level) being most affected. Curtailment thresholds may require a margin to account for the latency of the ANM system.

In terms of RTU suitability, some DNOs already have a number of “smart” RTUs operating on their networks while many others are undertaking extensive RTU replacement during RIIO-ED1 to ensure these assets are fit to manage the more advanced tasks that will be required of them in the future. It is also worth noting that existing RTUs are not always suitable for operating in harsh environments, although this technology is developing.

As networks become “busier” in the future, more ANM-connected customers and increased demand will cause networks to operate closer to their limits. As a result of this, faster response times may be required overall thus necessitating faster data polling rates and potentially a step-change in the communications platforms currently in use by the DNOs. However, SCADA and communications requirements will still be project-specific and not dependent on the timing of a connection.

4.2.2.4 Communications Infrastructure and Protocols

The specific communication requirements for an ANM scheme will depend on the architecture of the scheme, whether centralised or decentralised, and its operational characteristics as set out in the functional specification. Communications infrastructure can be based on a physical connection (e.g. fibre), GSM, GPRS, 3G, VHF, microwave or satellite.

The distinction between decentralised and centralised architectures is in the internal ANM communications and also in the SCADA protocols employed. The DNO will include the following specifications in a functional specification:

- **Communication Links**
  Centralised ANM schemes will utilise existing communication links where possible. For decentralised ANM schemes however, there may not be existing network communication assets that are available or appropriate for communication between remote devices. If new assets are deployed, the technology itself and the protocols are likely to be more modern and advanced than the existing assets.

- **Communication Protocols**
  Customer connection agreements do not specify communication protocols so where a customer control system is included in an ANM scheme, the applicable protocol is accepted. It should be detailed in any functional specifications that a vendor ANM scheme must be capable of interfacing with any existing DNO protocols, some of which may be considered “legacy”. Decentralised ANM schemes have tended to be “black box” solutions whereby the DNO has no visibility of the algorithms and this is symptomatic of the challenges in integrating with existing systems. As highlighted by UK Power Networks’ FPP project[36], considerable effort is required to integrate individual customers due to the variation of control system technologies used by Distributed Generation (DG) customers. There is a need to standardise the communication design to achieve vendor agnostic interoperability to reduce efforts in integration and operational support

- **Redundancy**
  Adequate communications redundancy should be provided. This will be dependent on the size of the ANM scheme and the criticality of a link or asset (e.g. whether large volumes of other traffic also rely on the link). There may also be a Failure Modes & Defect Analysis (FMDA) assessment undertaken to establish reliability. It is recommended to interface with the third party (with the exception of the customer) at the Operation zone (Wide Area Network) rather than at the station zone (field Local Area Network) for better management of these connections.

- **Third Party Communications**
  A number of ANM schemes allow the connection of third party communications (e.g. 3G or GSM) onto their data acquisition system. Whilst this reduces the costs associated with the implementation of an ANM scheme, there are security challenges associated with allowing a third party access to the DNO communications infrastructure or for DNOs when piggy-backing on third party networks. In addition, these communications networks are less resilient, which may increase the risk of curtailment.

- **Cyber Security**
  Cyber security aims to ensure that a system remains secure with regards to all Information and Communications Technology (ICT) components and sub-systems, including third parties, connecting to a communications and SCADA system. The most fundamental requirement for sound cyber security is to establish suitable electronic and physical security perimeters and the associated access points. Traditionally, DNO and customer networks have not connected with the ICT interface. This link poses a significant cyber security risk.

  With the connection of ANM schemes and control devices located in remote areas, the physical security of ICT equipment becomes an increasing security concern. Remote ANM scheme control devices may potentially have links into the central real-time systems of a network, where the NMS resides and so their physical location must be afforded considerable consideration and appropriate security such that the aforementioned risk to cyber security is mitigated.

  A cyber security assessment should take account of risk and vulnerability, and set out methods of prevention and response to all identified issues to minimise threats including enhancement of existing policies, processes and practices.[37]

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[36] http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Flexible-Plug-and-Play-(FPP)/Project-Documents/FPP%20SDRC%209.6%20-%20Implementation%20of%20active%20voltage%20and%20active%20power%20flow%20management.pdf

[37] Cyber security has been implemented with the whole systems approach within the UK Power Networks FPP project and a smart grid cyber security framework has been developed.

4.2.2.5 Forecasting

Forecasting functionality is not incorporated into UK-deployed ANM schemes at present, with the exception of Scottish and Southern Energy Power Distribution’s Northern Isles New Energy Solutions (NINES) project on Shetland. The NINES ANM scheme was designed to incorporate weather, wind and customer demand forecasting.

In terms of generation output forecasting, an accepted technique is to use the output profile of an existing generator (of the same type) to inform how a new generator will perform and behave. The development and integration of sophisticated solar and wind forecasting in future will enable more efficient performance of both the ANM scheme and its connected assets to maximise generation output and minimise curtailment. Accurate visibility and forecasting would permit the discrimination of certain protection failsafe timescales to be increased just long enough to allow ANM to intervene. For example, if a fault is detected in less than 10 ms but it takes between 2 and 3 seconds for an ANM-connected generator to respond to a curtailment signal, then the intertrip will have already operated and the generation site would be disconnected. If the intertrip discrimination timescales were to be increased slightly then perhaps only the necessary amount of generation would be curtailed rather than the full amount, as would be the case when an intertrip operates. This would introduce a certain level of risk due to uncertainty inherent in forecasting which would need to be considered and mitigated.

With limited current good practice on forecasting for ANM, it is recommended to specify that an ANM scheme should be capable of supporting forecasting activity (even if it does not provide it) to “future proof” for wider incorporation of this functionality. Of particular importance will be the ability to provide a forecast to the TSO for use in future (when ANM output becomes a more reliable indicator than Grid Supply Point (GSP) demand patterns) to inform the BM and could form part of the inter-network commercial arrangements discussed later in Section 5.

Section 4.2.2
Good Practice: Functional specifications

- Where existing communications assets are to be used, the network SCADA measurement and polling rates should be assessed for their suitability to support the ANM scheme performance requirements. Alternatively, modifications could be made, or new assets may be required
- The latency and reliability of ANM operation should be assessed to ensure this will not adversely affect scheme efficacy. Curtailment thresholds may include a buffer to account for the latency of the ANM system.
- DNOs should specify what existing systems and protocols the ANM scheme must be capable of interfacing with
- There should be adequate communications redundancy as appropriate for the application
- Consideration of security issues and network protection are needed prior to deployment

4.2.3 Control Room Visibility

4.2.3.1 Introduction

It is essential that the DNO control room has visibility of ANM schemes such that they can effectively operate and manage their networks. Control engineers are provided with the two main methods of interaction with an ANM scheme:

- Two-way exchange encompassing incoming SCADA notifications and outgoing control signals
- An interface which provides an overview of a scheme, either directly through the NMS or via a stand-alone ANM management server in the control room.

These ensure the control room has appropriate visibility over an ANM scheme, and are explored further in the following sections.

4.2.3.2 Two-way Interactions

The interaction between a DNO and an ANM scheme will be bi-directional, involving the receipt of information and data and the execution of control actions.

- **Receipt of Information**
  Information provided to the control engineers from an ANM scheme encompasses key information about ANM hardware and assets as well as any connected generation or demand customers and communications. Alarms and indications will appear in the SCADA log alongside existing network SCADA notifications if fully integrated with the NMS.

  In terms of good practice, it is prudent to provide at least the following information to the control room in the form of alarms and indications:

  - ANM scheme status (enabled/disabled)
  - Equipment status indications (e.g. circuit breaker position)
  - Change in customer connection status (connected/disconnected)
  - Non-response & failure alarms
  - Change in parameter set-point (e.g. ANM customer MW output)
  - Communications & SCADA failures
  - Parameter in excess of limit (e.g. Voltage at GSP, current/MVA flow on a circuit)
  - Customer output in excess of set-point

In terms of good practice for analogues, all measured parameters, encompassing network measurements and customer outputs, should be accounted for. Network analogue values are normally updated automatically in the NMS topology diagram while ANM analogues and customer outputs can be updated in a suitable interface between ANM and the NMS (described further in Section 4.2.3.3).

- **Execution of Control**
  Control engineers are afforded a number of controls over ANM in accordance with their agreed responsibilities and the characteristics of the scheme itself. The control room can take manual control of the ANM scheme if required and as a minimum has the ability to enable and disable it. Other control actions can include:

  - Specify generator output set-point
  - Connect/disconnect generator
  - Vary ANM thresholds in case of abnormal events

The autonomous nature of ANM schemes means that there is minimal need for the control engineer to interact with the scheme whilst it is within its operational envelope (during network normal and contingency conditions). In the event that control room intervention is required however (e.g. in storm conditions) it is good practice that the execution of controls is accessible from within the ANM Human Machine Interface (HMI).

4.2.3.3 Interfacing

An interface between ANM and NMS which provides indication and control of the ANM scheme operation is specified to the control engineers' requirements. Real-time indication and control can be spread across the relevant network points on the main NMS diagram, which aligns closely with day-to-day operation of the network.

Alternatively, an HMI "dashboard" is often used and this is commonly placed within the DNO's existing NMS topology diagram. For ease of access, the dashboard is normally placed adjacent to the area of network where the ANM scheme is deployed.

The main purpose of the dashboard is to provide the control room with a concise real-time overview of the ANM scheme and the operational status of connected assets. Execution of control actions (such as those described in Section 4.2.3.2) can also be made available from within this interface.

4.2.3.4 Reporting

Part of the duties of the control room is to provide operational reports on the network. ANM schemes should also be included in any reporting activity once they have been deployed. Network analogues are traditionally logged and archived in a data historian tool and it is this tool which is used to generate reports. Analogues from an ANM scheme should be mapped such that they are also logged and archived in the data historian tool and they can be easily included.

4.2.3.5 Control Engineer Training

Control engineer training and familiarisation with an ANM scheme is a requirement of the integration process[38]. The control room must be made aware of a scheme and any implications it has for network operation and management. Training methods vary with each DNO and can be anything from provision of technical manuals to setting up offline NMS demonstrations.

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[38] Note that broader training requirements for ANM implementation are described in Section 4.3.3

These should serve to build the required confidence level in control engineers when it is necessary for them to take action.
In addition to training on the technical aspects of an ANM scheme, it is important to instruct control engineers about the commercial aspects of a scheme, and the ramifications that their technical decisions could potentially have from a commercial perspective. It should be acknowledged that network safety will always take priority and this may necessitate actions which conflict with commercial arrangements (e.g. the generation curtailment order deviating from the LIFO stack).

Section 4.2.3
Good Practice: Control room

- Control engineer responsibility should be agreed in the early stages of the integration process to ensure the correct SCADA notifications and controls are provided
- A Human Machine Interface (HMI) "dashboard" should be provided within the Network Management System with ANM scheme overview
- Controls should be made accessible from within the HMI
- Adequate training and familiarisation should be provided to control engineers on ANM scheme operation and accompanying HMI

4.2.4 ANM failsafe modes

4.2.4.1 Introduction

As with all assets installed on the network, an ANM scheme is required to operate in such a manner that it is not detrimental to the safety and security of the network, including the transmission network. Network safety in this context is the requirement that any asset connected to a network should not cause harm to the overall operation of the network in the event of a failure. Failsafe modes are integral to the design of an ANM scheme to ensure that operator intervention is minimised as far as possible.

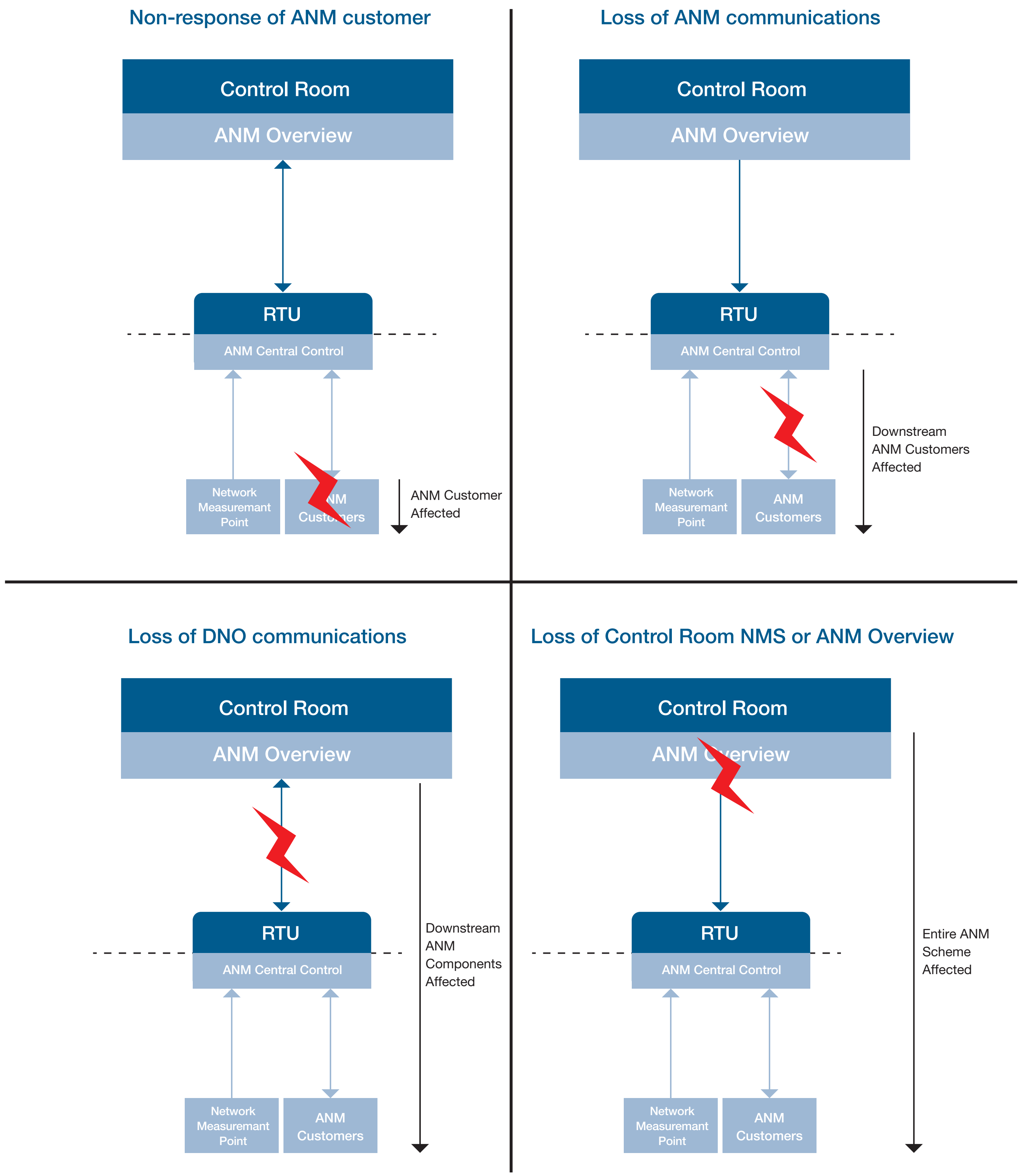
Failsafe requirements are detailed in the functional specification provided by DNOs. Although these will differ in the detail with each DNO, commonality and good practice can be drawn out across the four main failsafe modes described in the sections to follow. Figure 9 and Figure 10, illustrate the four main failsafe modes both for decentralised and centralised ANM scheme architectures respectively, highlighting the points of failure for each and the implications for any downstream equipment.

The four main failsafe modes for ANM are considered to be:

- Technical non-response of ANM customer
- Loss of local/ANM communications
- Loss of central/network communications
- Loss of ANM scheme or individual components

Each of these failsafe modes is applicable to ANM schemes of all architectures. It is important to note that failsafe modes will vary depending on the size of an ANM scheme as well as the location. Additionally, the TSO may request different failsafe modes from the DNO in respect of the same scheme. There may be special conditions that are imposed during extreme events (e.g. storms), which will be DNO-dependent.

Figure 9 **Decentralised ANM Scheme Architecture Points of Failure**



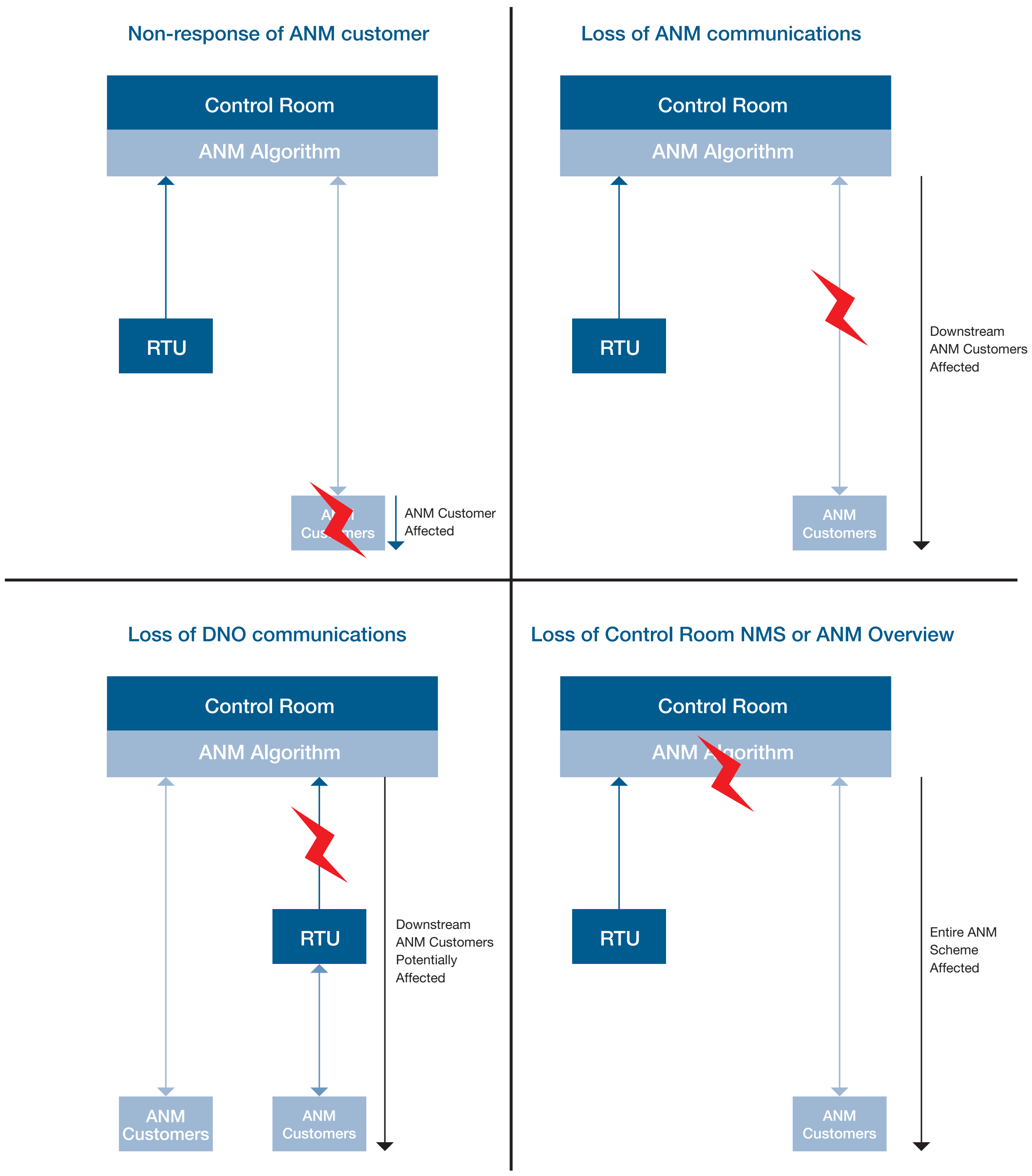
Non-response of ANM customer

Loss of ANM communications

Loss of DNO communications

Loss of Control Room NMS or ANM Overview

Figure 10 **Centralised ANM Scheme Architecture Points of Failure**



Non-response of ANM customer

Loss of ANM communications

Loss of DNO communications

Loss of Control Room NMS or ANM Overview

4.2.4.2 Technical non-response of ANM customer

For ANM schemes constraining generation customers, the non-response of an ANM customer prompts an ANM scheme to disconnect the customer in question, or constrain the output of the customer to a failsafe level, until such times as it becomes responsive. The window for non-response varies between DNOs but is in the region of 2-3 minutes, although this time frame may reduce as networks become increasingly populated with generation. An additional offering by some DNOs is a “three strikes and you’re out” policy where non-responsive ANM customers have three windows to respond before they are disconnected. This again may be reduced as networks become busier.

The effects of this failsafe mode are the same for both centralised and decentralised ANM schemes in that it is only the non-responsive customer that is directly affected. Other ANM customers may be indirectly affected (e.g. being requested to change output level).

Reconnection of Lost Customers
Where an ANM scheme is not constraining generation, but is focused on network demand management, it may be the case that the incentive lies with the DNO to rectify an issue and reconnect customers should they become disconnected due to failure attributable to the DNO (e.g. the loss of hardware equipment).

4.2.4.3 Loss of Local/ANM Communications

The loss of local or ANM communications can potentially impact all downstream ANM customers serviced by the failed link. Depending on the criticality of the affected communication link and scheme specification, ANM-connected customers will either be disconnected or constrained to a failsafe output level.

At present, the failsafe level of generation is 0 MW. It should be noted, however, that this level could increase from 0 MW in future as total disconnection of customers can also affect the local voltage as well as having wider implications for the transmission network (which are considered in Section 5). It may be the case that failsafe design will be specific to ANM schemes in the future.

To an extent, existing automation on the network deals with communications failures on the distribution network. However, this becomes more complex when considering the interaction with the transmission network assets and balancing mechanisms.

4.2.4.4 Loss of Central/Network Communications

The loss of central or network communications is more severe than the loss of local communications regardless of the ANM scheme architecture. For a decentralised ANM architecture, Figure 9 above highlights the impact of a central communication link failure whereby all ANM-connected devices and customers downstream of the link are affected. Other branches (connected radially out from the control room as illustrated in Figure 7 previously) of the same ANM scheme could potentially continue to operate unaffected.

Figure 10 above illustrates the same failsafe mode for a centralised scheme. The loss of a communications link to an RTU means the ANM scheme loses visibility of a large area of network and this can impact all ANM-connected customers.

Depending on the criticality of the affected communication link and scheme specification, ANM-connected customers will either be disconnected or constrained to a failsafe output level (as before, this is not always 0 MW).

Having said that, as described in Section 4.2.2.4, the communications system specified for an ANM scheme should contain an appropriate level of redundancy. In the case where there is dual redundancy available at central control level, communications to the ANM scheme would switch to the back-up facilities with minimal disruption to the downstream equipment.

4.2.4.5 Loss of ANM Scheme

Loss of the ANM scheme in its entirety can occur in a number of situations:

- Emergency conditions where the network is outside the ANM scheme’s operational envelope (e.g. severe storm conditions)
- Emergency conditions where there is a critical NMS failure
- Non-emergency conditions where the control room actively disables it (e.g. for maintenance)

The loss of the ANM scheme in emergency conditions is dealt with by the disconnection of all ANM customers. When the ANM is disabled as part of planned maintenance however, then the sequential constraining of customers can occur in advance. The impacts of this failsafe mode are the same regardless of ANM scheme architecture. One DNO in particular is in the process of installing overload protection as a contingency for its ANM-connected assets in case of the loss of the ANM scheme.

Section 4.2.4
Good Practice:
ANM failsafe modes

- Failsafe modes must be integral to an ANM scheme algorithm
- Non-responsive generation is disconnected or constrained to failsafe level
- Generation is disconnected or constrained to failsafe level upon loss of communication unless back-up communications are available
- Generation is disconnected or constrained to failsafe level upon loss or disabling of the ANM scheme
- Failsafe level of generation is 0 MW but this could change in future owing to local considerations and constraints

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4.3
People & process considerations

4.3.1 Introduction

Most of the ANM activity that has been undertaken by DNOs to date has been as a part of innovation projects. Some DNOs have started to deploy ANM as Business as Usual, whereas others have seen minimal roll-out except for a few isolated instances.

Section 3 described some of the procedural changes that might be required in order to use ANM for certain applications. There are also more general changes that DNOs need to make to their operations and training (in addition to the technical changes described in Section 4.2) in order to embed ANM into the business’ day to day activities.

Table 10 Considerations for making a zone ANM-enabled

Transitioning ANM to Business as Usual	> Which functions are responsible for implementing and operating ANM?
	> What changes to existing departments are required, and what new departments might need to be created?
	> What training is needed for the people in those departments?

4.3.2 Departmental responsibility for ANM

In the majority of cases, ANM to date has been implemented using a small innovation or R&D team interacting with the operational parts of the business. It has been suggested that during an R&D phase it makes sense to minimise the amount of effort required by the wider business, but that once the trial phase is over the systems and people need to be in a position to roll ANM out more widely.
As ANM becomes more widespread, there is likely to be a need for new operating models, in particular to manage the ongoing engagement and information exchange requirements for ANM systems. DNOs may be organised in different ways, but some of the key functions that will be affected by ANM are:

- **Connections**, who may need to be involved in the decision to make a network zone ANM enabled, calculate curtailment assessments (if offered), and create ANM connection offers
- **Network design**, who would assess the impact of ANM connections on the network, particularly on more complex parts of the network
- **Network planning**, who would ensure that its network (and the transmission network) can cope with the pipeline of expected connections (both Conventional and ANM), and either identify or facilitate the identification of DSR candidates
- **ICT**, who may need to update DNO computer systems
- **Contact centres**, who would need to receive queries from customers using ANM systems
- **Field teams**, who may be tasked with installing, maintaining and repairing some aspects of the ANM equipment
- **Control room and other operational functions** will need to alter their day-to-day activities to adapt to actions being taken by ANM, and to know when and how to intervene if required

Many, if not all, members of these departments may need to understand and interact with ANM, and would ideally be involved in the early stages of its implementation to ensure a smooth transition. One recommendation is to identify a suitable business owner who can be primarily responsible for ANM. These nominated individuals would be responsible for integrating ANM into their functions, and coordinating any training required. On an ongoing basis they would also ensure that the necessary knowledge is transferred between and within the teams.

There may also be a role for a dedicated ANM team to coordinate the departmental ANM business owners, perhaps acting as ANM support teams. This could be a relatively small role, allowing the different departments to carry out most of the work. However, as ANM becomes used more widely, a dedicated ANM systems management team may be appropriate, not only to coordinate the activities of existing departments, but to manage the relationship with the ANM service provider, along with any ongoing maintenance and support of the ANM systems themselves.

4.3.3 Training

However DNOs choose to structure their organisations to implement ANM, some degree of guidance or training will be required. This may take the form of formal training, ongoing support, manuals, user guides or tools. Topics may include:

- Understanding ANM's technical details to the extent necessary for the DNO (noting that much of the detailed knowledge may be appropriately held by the ANM Service Provider)
- Understanding how to carry out Cost Benefit Analysis, understanding whole-life costs and calculating Net Present Values (NPVs)
- Using modelling tools in new ways to plan the network
- Using the ICT platform supporting ANM, and understanding how it interacts with existing control systems
- Designing a connection or DSR scheme that uses ANM
- Commercial and contractual design, including economic assessment of DSR schemes and ANM connection offers
- Client engagement and relationship management, including negotiation with customers and service providers
- Curtailment assessments (if performed by the DNO), and communicating those assessments to customers
- Record keeping and data management to monitor and audit ANM actions
- Maintenance and fault resolution
- ANM system training for helpline staff

Section 4.3
Good Practice: People & processes

- ANM affects multiple stakeholders within a network business, each of whom would ideally be brought on board early in the implementation to smooth the transition
- Suitable business owners in each department should be identified to coordinate the ANM scheme
- A central ANM team will help with coordination efforts, but does not need to be a large function until the ANM scheme is more fully implemented
- Effective training will be important, and may take the form of formal training, ongoing support, manuals, user guides or tools
- Training will need to cover a wide range of subjects including technical proficiency, commercial negotiations and data management

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Interactions between networks

5

5.1
Introduction

One important difference between today's distribution and transmission networks as they relate to ANM, is that the transmission networks are managed by a single TSO, National Grid, who can take actions on Balancing Mechanism Units (BMUs) and other balancing service providers to manage flows on the network, whereas the DNOs have traditionally been responsible for ensuring that their own networks meet security standards without any mechanism to adjust generation and demand positions. Many of the balancing services that National Grid procure, are naturally embedded within the distribution networks.

ANM allows DNOs to take more active control of their networks and hence is one of the enablers as DNOs start to take on a limited role in system operation which could evolve (with suitable changes to technology, regulation and incentives) into the role of Distribution System Operator (DSO). The future role of ANM is explored in more detail in Section 6, but even with ANM taking on the more limited role that is seen today, there is a growing requirement to coordinate operations across the distribution and transmission systems.

The following sections consider some of the issues that can arise between transmission and distribution when ANM is used, and what information or control systems may be required to alleviate them.

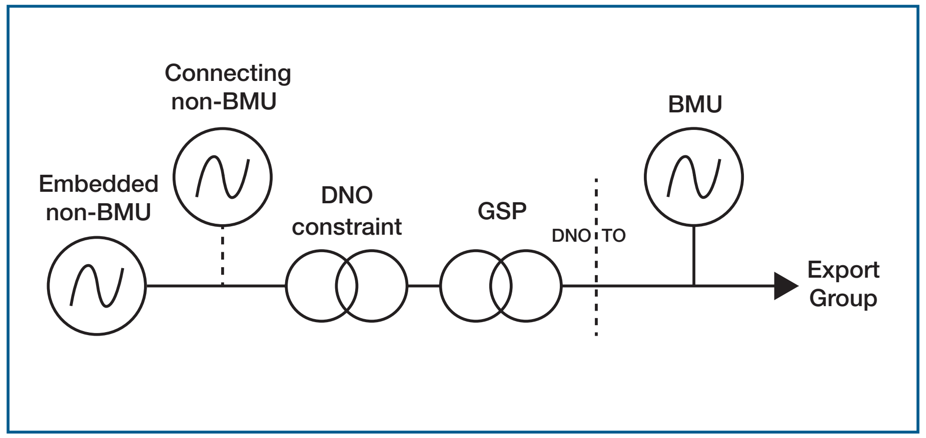
5.2
Inter-network issues

5.2.1 Inter-network issues that exist without ANM

Even without the introduction of ANM connections, new challenges are arising for the TSO as a result of the rapid uptake of distributed renewable generation, and micro-generation such as rooftop solar PV. This rapid uptake, and the fact that this capacity is not typically visible to the TSO, can give rise to a number of issues:

- A large uptake of embedded generation and/or reduction in demand can require the reinforcement of an export-constrained transmission network (illustrated in Figure 11). This may not only be expensive, but may not be feasible in the timescales required.

Figure 11 Connected embedded generation driving transmission constraint



- In this export-constrained example, if reinforcement is not feasible, the TSO may need to curtail transmission-connected generation through the BM or other Balancing Services. The cost of these balancing actions will fall to the TSO, and ultimately be passed through to all customers through Balancing Services Use of System (BSUoS) charges. Because network constraints are local, the TSO may be required to curtail low-short-run cost or low-carbon generation such as wind. Additional ANM-connected embedded generation, therefore, can result in outcomes that impose additional costs on consumers and displace other forms of low carbon generation, thus negating some of the carbon benefits.
- On both import- and export-constrained networks, having an unknown capacity of small-scale generation on the system makes forecasting future net demand growth more challenging for the TSO, meaning that planned network reinforcement is more likely to be carried out too early or too late.
- In operational timescales, the TSO needs to balance the system, which requires forecasting minute by minute changes in net demand. Traditionally, this has involved the use of statistical demand profiles and weather patterns, which influence the domestic, commercial and industrial energy behaviour. Large volumes of 'hidden' embedded generation can make this demand less predictable, particularly in the case of solar PV where electrical output from multiple units can change rapidly and near-simultaneously as a result of a change in cloud cover. ANM further complicates the forecasting process, as such schemes can potentially distort the historic demand consumption patterns (though the impact is currently negligible). Therefore there will be a need to predict and understand the output of such schemes, along with advanced visibility of the constrained services within them.

Larger embedded generators connecting under a G59 application[39] can create similar issues for the TSO. In order to mitigate the risk that embedded generation has an adverse impact on the transmission network, a Statement of Works (SoW) process has been implemented. A DNO requests a SoW from National Grid if it "reasonably believes the given connection may have a significant impact on the transmission system"[40]. If any works are identified the connection cannot be energised until those works are completed. Whether or not works are required, the SoW process adds considerable time to the overall connection of an embedded generator.

Thresholds for triggering the SoW process are agreed between the DNOs and the TSO, and are summarised in Table 11. However, the ultimate decision as to whether or not a connection will have an impact on the transmission system lies with the DNO[41]. In some parts of the electricity network such as Scotland, it is well known that the transmission system is constrained, so SoWs are commonly requested.

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[39] Large Generation or G59 Generation connections refer to all non G83 generation connections (above 16 amps per phase). The connection process for these larger G59 generators is more complex than for G83s.

[40] https://www.ofgem.gov.uk/ofgem-publications/52813/tar.pdf

[41] http://www.energynetworks.org/modx/assets/images/events/DG%20Fora/2014/London/DGF_London_3_Transmission%20Distribution%20Interface.pdf

Table 11 Thresholds for Statement of Works[42]

Area	DNO	Likely size when SOW would apply (for individual projects)	Cumulative limits[43] (for individual GSPs)	Exceptions
Northern Scotland	Scottish Hydro Electric Power Distribution	1 MW		Shetland – assessment made by DNO for each application
Southern Scotland	Scottish Power Distribution	Not currently available[44]		
North East England	Northern Powergrid (North East)	50 MW	50 MW	10 MW Blyth 40MW Fourstones
Yorkshire	Northern Powergrid (Yorkshire)	50 MW	50 MW	10 MW Grimsby West 30MW Keadby 10 MW Saltend North 10MW Drax (132kV connection) 25MW Drax (sub 132kV MW connection)
East Midlands	Western Power Distribution East Midlands	Currently under discussion		
North West	Electricity North West	Currently under discussion		
North Wales, Merseyside	SP Manweb	Currently under discussion		
West Midlands	Western Power Distribution West Midlands	30 MW	50 MW	
South Wales	Western Power Distribution South Wales	30 MW	50 MW	
South West England	Western Power Distribution South West	30 MW	50 MW	
Southern England	Southern Electric Power Distribution	10 MW	50 MW	
London	UK Power Networks (London)	10 MW	50 MW	
Eastern England	UK Power Networks (Eastern)	10 MW	50 MW	
South East England	UK Power Networks (South)	10 MW	50 MW	

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[42] http://www2.nationalgrid.com/WorkArea/DownloadAsset.aspx?id=24678, last updated March 2012

[43] The "cumulative limit" applies to the first and subsequent generators to exceed the GSP limit (MW). The DNO is likely to apply for a SOW for the generator that breaches the cumulative GSP limit, and any generator applying to connect behind the GSP from that time onwards.

[44] As the need for a SoW is not always apparent, in Southern Scotland this is assessed on a case by case basis

These thresholds are not fixed, and can be reduced if smaller generators start causing issues on the transmission network. This may be more likely if large volumes of embedded generation are connected under ANM, which will drive up the utilisation of the networks.

5.2.2 Issues created or exacerbated by ANM

ANM has the potential to exacerbate existing issues and introduce new problems that the TSO would need to manage[45]. These issues are expected to become more material as ANM becomes more widely used, so they should be addressed while the technology remains at relatively low levels of deployment.

Issue 1: Distribution ANM exacerbates transmission reinforcement and BMU curtailment
ANM allows the DNO to increase the amount of embedded generation on a given part of the network. In those situations where the transmission network is export constrained, ANM can therefore increase the requirement for transmission reinforcement, and the cost of BMU curtailment actions prior to reinforcement, which could result in higher customer costs.

It may be that the transmission constraint periods coincide with the DNO constraint periods. For example, if both constraints are primarily the result of wind generation, both networks may be constrained during high-wind low-demand periods. In these periods, the action of the ANM system may help to alleviate the transmission constraint. However, the correlation is unlikely to be perfect, and may therefore be insufficient for the TSO to avoid the additional reinforcement (and note that the network is still likely to have a higher load factor than if the ANM-connected generation had not been built).

Indeed, the correlation that does exist between DNO and transmission constraints may make the task of forecasting the need for transmission reinforcement more difficult. Since the TSO cannot see when the ANM system is acting, it cannot know whether the net load it observes on the network includes or excludes the contribution of the ANM-connected embedded generator.

Issue 2: ANM can undermine balancing actions
ANM can undermine actions taken by the TSO to balance the transmission network. One network configuration that can give rise to this issue is given in Figure 12.

Figure 12 Example of ANM undoing a balancing action

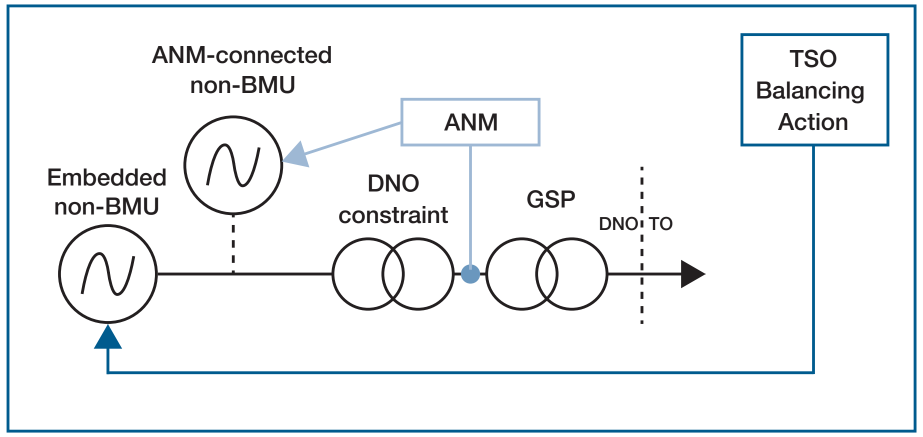

Figure 12 describes a situation in which the TSO determines that a balancing action is required (e.g. frequency response), and issues a Bid Offer Acceptance (BOA) to an embedded BMU. On the same part of the distribution network, a non-BMU is connected under an ANM connection[46]. The potential conflict in this situation arises as follows:

1. The TSO issues an instruction to an embedded BMU to be ready to provide frequency response. The BMU then monitors the frequency of the system and, if it observes an increase or decrease in frequency, it will curtail or increase its output accordingly to bring the frequency back with its allowed limits.
2. Prior to this, an embedded non-BMU has been connected under an ANM connection agreement. The distribution network is constrained, and the embedded non-BMU is being curtailed by the ANM system.
3. As soon as the embedded BMU curtails or increases its output to manage the system frequency, the ANM system observes the change in export across the constrained point in the network. It instantaneously increases or decreases the embedded non-BMU's export set point in response.
4. The net result of these actions is that the TSO has paid the embedded BMU for frequency response, but the frequency reduction has been partially or completely offset by the increase in non-BMU generation. Unless the TSO can intervene to limit the ANM's behaviour in some way, it could require the TSO to call on additional balancing actions (at increased cost) or for the network to go outside its operational limits.

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[45] Note that suppliers with offtake agreements with ANM-connected generators are also potentially affected since they are exposed to resulting imbalances caused by curtailment actions

[46] There is a variant of this case in which both of these generators are BMUs, one being controlled by an ANM and both actively participating in the BM

This example is not limited to frequency response – similar issues can occur with any balancing action taken in this situation. However, it will only occur where the TSO is taking actions on an embedded BMU or a non-BMU contracted for balancing services.

The transmission issues arising from increased embedded generation are being managed at present, and protocols are being put in place to mitigate their impact. There is, however, a need to review the interaction between the TSO and DNOs to cope with the effects of ANM on TSO balancing actions. What level of interaction may be required is discussed in the next section.

5.3
Required inter-network information and control

In order to avoid some of the unwanted conflicts described above, some interaction needs to take place between the DNO's ANM system and the TSO's control room. Ideally, there would be a fully integrated communications between the TSO, DNO and ANM systems to ensure that any actions taken by any party result in the expected behaviour. Without this integrated approach, the TSO may still need to be able to have some influence over ANM behaviour, or at least to be informed about ANM schemes in operation:

- **TSO can influence ANM directly or via DNO**
  One option is for the TSO to have control over the ANM system, actively managing it in conjunction with balancing actions to ensure the overall system works as intended. This approach may be unworkable for three reasons:

  - Because the ANM system is designed to make autonomous decisions in real-time, it may not be technically possible to control the system (e.g. via SCADA) on the required timescales
  - The TSO action could prevent an ANM action required by the DNO in order to keep the distribution system within acceptable limits
  - Real-time control would also increase the complexity of the roles carried out in the TSO control room

  Whatever the difficulties associated with implementing it, there will need to be some way for ANM behaviour to change in response to BM actions if the BM is to operate correctly. An alternative model is for the TSO to effect real-time control indirectly via the DNO.

Whatever the difficulties associated with implementing it, there will need to be some way for ANM behaviour to change in response to BM actions if the BM is to operate correctly. An alternative model is for the TSO to effect real-time control indirectly via the DNO.

A variant on this approach is that the TSO could limit the function of ANM minutes or hours ahead of time. For example, it could suspend or limit ANM operation when a BMU is on frequency response, or ask the DNO to do so. This may address the latency and complexity issues associated with real-time ANM control, but presents a commercial risk for the ANM-connected generator (who may be curtailed more than expected). It also adds a significant layer of complexity to the principles of access under which generators are curtailed.

- **Increasing information-sharing by the DNOs**
  Another option is simply for the DNO to provide more information to the TSO. There are security issues associated with providing real time information from the NMS of another network operator, although this has been achieved in the recent past in GB between DNOs and the TSO using the ICCP (Inter-Control Centre Communications Protocol) in order to share real-time SCADA data between systems. The main purpose of linking a DNO system with the TSO is to give the TSO more visibility of distribution networks. However, there are also clear benefits for DNOs.

The type of information a TSO would benefit from regarding distribution-connected ANM includes:

- Visibility of ANM-connected generation and latent demand
- Visibility of contracts not associated with an ANM scheme
- Interactions between an embedded BMU and an ANM-connected generator
- How much generation the ANM is forecast to constrain, ahead of real-time[47]
- ANM scheme control range and behaviour (e.g. ramp rate, failsafe mode actions)
- Availability of all grid services under a GSP

This information is not necessarily required in real-time as it is intended more to facilitate improved understanding of ANM behaviour.

When providing information to a TSO, the philosophy of "information is better than data" applies as the TSO may not need specific ANM scheme SCADA data and notifications but rather an overview of each scheme and its expected behaviour under certain network conditions. Ideally there should be a harmonised system where this information can easily be exchanged between the DNOs and the TSO and this will become increasingly important as more and more ANM is deployed.

Section 5
Good Practice: Network interactions

- Inter-network protocols should be identified to ensure interactions between networks are managed effectively and efficiently
- If the TSO is to have influence over distribution ANM, this should be reflected in the customer's connection agreement
- Information exchange should focus on understanding how ANM will behave rather than communicating real-time information about specific ANM actions
- In order to allow the Balancing Mechanism (BM) to operate effectively, ANM behaviour must change in response to BM actions in the same network zone

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[47] Existing ANM technology is not designed to assess what generation output would have been without curtailment or to forecast future constraints. This may need to change in future, particularly if generators are to be paid for curtailment, which is one option discussed in Section 6.

6

Future developments

6.1
Introduction

The majority of this guide concerns good practice that can be employed by network operators today when choosing and implementing an ANM scheme. ANM as a technology remains relatively novel, and is expected to evolve over the coming years, becoming increasingly responsive, reliable and widespread. The commercial arrangements around ANM are also likely to become more sophisticated, and the regulations, codes and market designs relating to the electricity networks are also likely to change as these new technologies become more established. As this happens, ANM may become suitable for a wider range of applications.

6.2
Evolution of technology

Technology is continually evolving and this will impact the design and implementation of future ANM schemes. Communications are commonly considered to be the single biggest technology challenge for ANM deployment at distribution level (and future networks as a whole). From a TSO perspective however, the major challenge of ANM will come from controllability and the need for a well-defined control hierarchy.

The following sections highlight a number of key technical considerations that will influence how ANM and its associated good practice evolves, and the changes to the engineering guidance that may facilitate this evolution.

> **Communications converge on a common standard**
It is widely agreed that a common platform that enables multiple protocols to operate and interact is a highly recommended, if not necessary, next step for network operators anticipating extensive deployment of ANM and other new technology. Also, in GB there is convergence towards industry standards such as the use of IEC 61850, the substation automation design standard, and also Distributed Network Protocol (DNP3). This will not only allow greater integration with generation and network control and protection systems, it will also help to facilitate multi-vendor schemes (which are not currently available) and lead to more efficient procurement. Standardisation such as this should reduce challenges associated with interfacing with existing systems and protocols.

As it stands, there are no instances where a deployed ANM scheme must interact with another; they are all geographically discrete. This development will also facilitate future interaction between schemes as ANM becomes more widespread and improved scalability with new equipment able to be easily added and interfaced.

The standardisation of communications protocol between DNO and customer in the context of GB industry will require liaison with GB and international standardisation bodies and industry working groups.

> **ANM technology becomes embedded in DNO field devices**
In future, from a DNO perspective, it would be preferable to embed ANM software on DNO-owned field devices such as RTUs. However, this depends on the required response time of the scheme which may be influenced by the requirement to interface with failsafe tripping schemes for example. This will not only reduce the amount of new hardware being installed on networks, it will also facilitate smooth integration with the DNO's SCADA systems. Furthermore, if ANM evolved down a defined software route then there would be the opportunity to embed ANM algorithms within the generator inverters of ANM-connected customers. Co-ordination of generator response will need to be carefully considered which may be via a hardware control interface at the point of generation connection to the network.

6.3 Evolution of network operation practices

The practices covering the operation of the network are expected to change in a number of ways, including:

> **Engineering Recommendation P2/6**
There is presently a review being undertaken of Engineering Recommendation P2/6, the Security of Supply Standard to assess how it might be updated to better consider the impact of recent developments in distribution networks, such as increasing levels of embedded generation and more active networks, on security. The review is examining a number of factors which affect security of supply at distribution level, including ANM.

The impact of ANM itself, and the increasing number of flexible connection contracts offered to distributed generation through ANM schemes, challenges the traditional notion of security of supply and the capability of a network to meet demand following critical outages. Any future revision of the standard should take these into account and anticipate future developments such that the standard remains valid in the coming years.

> **Extending Voltage Limits**
Statutory steady-state voltage limits in GB are being examined in greater detail through various research projects with a view to extending voltage limits and voltage step change limits on distribution networks beyond existing limits, where there is an acceptable techno-economic case. A major incentive to increase voltage limits is the creation of headroom for new generation connections. Generators connected on long, rural feeders are usually constrained by voltage.

6.4 Evolution of ANM applications

The current role for ANM is expected to be managing thermal constraints in order to keep the network within its pre-fault (intact) limits. As the technology becomes more responsive and develops a proven track record of reliable operation, it may be able to use ANM in new ways:

> **Voltage and reactive power management**
ANM should be capable of monitoring and controlling voltage and reactive power on the network. The ANM system should be able to trigger different actions depending on which constraint is binding at a particular time. Because both voltage and reactive power need to be managed locally, the set of suitable customers may be different from those used for managing thermal constraints. In the case of ANM connections, the principles of access would need to be refined to specify the rules under which a customer would be curtailed under each constraint type, and in the case where multiple constraints are binding simultaneously.

> **Post-fault operation**
ANM is already being used post-fault as part of Electricity North West's C2C trial. In this example ANM is used to restore supplies following a fault in such a way as to avoid exceeding the potentially reduced capacity of the post-fault network. Rather than restoring customer supplies, in future it may be possible to use ANM to prevent a loss of supply from occurring.

"Post-fault" operation in this context would mean operating the network above its firm capacity and using ANM to curtail customers immediately after a network fault to bring the system back within its thermal limits. In the time between the fault and the curtailment, network assets may be operating above their thermal limits. Typically assets have some thermal inertia which allows for this, but in order to prevent further failures the response time would need to be quick.

Post-fault operation should result in substantially lower payments to DSR providers than would be required under pre-fault operation, since they would only be utilised on the rare occasions when there was a network fault. It should be noted that post-fault DSR customers are often paid an availability fee alongside any utilisation payment.

To be suitable for application post-fault in the sense of ANM being the "first responder", the equipment would have to be of the same standard as protection equipment in terms of reaction time and reliability which is not presently the case. For longer term post-fault operation (i.e. a sustained N-1 condition) an ANM algorithm would have to be designed to adapt autonomously to the reconfigured network and potentially reduced capacity to perform control actions as necessary.

> **Relationship to protection systems**
ANM, in its current form, is unlikely to supersede existing protection systems. The devices and algorithms used do not have the response time capabilities or proven reliability required of protection-grade equipment. This capability is still a long way off and it is not certain whether ANM technology will or should develop towards protection, or indeed whether there would be a benefit to combining them. Currently, it can be used to compliment protection systems by managing networks to avoid protection having to operate (e.g. intertrip threshold breach avoided through generation output control).

> **Fault level management**
The use of ANM for fault level management was explored conceptually in UK Power Networks' LCL project and is being considered in Electricity North West's Fault Level Active Response (RESPOND) project. By monitoring back-up generators to ensure they were not synchronised with the network (and hence not contributing to fault level) this could allow additional generation to be connected under ANM to a fault level-constrained part of the network. On the rare occasions when the back-up generators did synchronise, the non-firm generators could be disconnected to keep the system within fault level limits.

It is not currently proposed to use ANM in this way. Any delay between detecting the synchronisation of a back-up generator and the curtailment of the non-firm generator leads to a period in which the system fault level exceeds the rating of the equipment serving that system, which is not allowed under Electricity Safety, Quality and Continuity Regulations (ESQCR).

> **More complex constraints management**
In future, ANM may be applied to manage more complex constraints such as transient overvoltage at TSO-DNO interface. However, this would be challenging to implement due to the rapid response required.

6.5 Emergence of a DSO role

Alongside the increasing deployment of ANM, DNOs are also rolling out other smart technologies and solutions to move towards a smart grid. By enabling DNOs to take more active control of their networks, these technologies, along with other enabling changes (to regulation, for example), may allow DNOs to take on some aspects of a DSO role. A DSO is responsible for actively managing the network using a range of operational tool and services, which may include indirectly or directly controlling connected customers (generation, demand and storage), and potentially making payments for the actions taken.

The development of smart grids and the DSO role is both wider in scope and longer in timeframe than the coverage of this Good Practice Guide. However, we consider some potential implications for ANM schemes below.

DNOs could move away from rule-based LIFO or pro-rata principles of access, and towards a price-based approach for curtailment more akin to the BM. Some generators may be willing to be curtailed for a lower fee than others, meaning that curtailment could be applied in a more economically efficient manner. Paying for curtailment would also give the DNOs the economic signals to reinforce at the appropriate time since the costs of both options would lie with a single entity. However, this would also require changes to connection charging to ensure that generators are paying for the additional value of a scheme in which they receive compensation for curtailment.

Whether paying for balancing or for curtailment, a means of determining the appropriate payment needs to be established once an instruction has been given. One issue is establishing what the customer would have been doing had the instruction not been given, since this determines the actual loss in revenue that the customer might face. A similar issue exists on the transmission network and National Grid is taking steps to improve this process.

A related question is how the ANM technology might need to evolve to allow it to be used to provide paid-for balancing services. Currently ANM reacts automatically and in real-time in response to a measured condition on the network. It is likely that the DSO would require forecasts of future ANM operation and the ability to plan set points ahead of real time. It is not clear at this stage how, having agreed that the DSO would provide a service to a TSO, the rules under which that service would be applied would be passed to, and enacted by, the ANM system.

The primary benefit of establishing DSOs is that it allows the distribution networks to be managed more efficiently, but it can also broaden the asset base from which the TSO can procure balancing services. Depending on how it evolves, the emergence of a DSO role could result in profound changes to the interactions between the transmission and distribution networks, and the way in which the whole electricity system is balanced. A number of models for the interaction between the DSO and TSO have been explored[48], including:

> **DSO as information provider**
The DSO operates the ANM systems, according to the rules or prices established for the schemes. The DSO notifies the TSO of those actions. The TSO may independently procure balancing services from distribution customers, perhaps via an aggregator.

> **DSO as TSO service provider**
Even without the development of a DSO role, in the shorter term it may be possible for DNOs to allow the TSO to access a limited set of balancing services from embedded generators. For example, ANM on embedded generation can be used to alleviate a specific transmission constraint (created by connection of new generation), as is being trialled under SP Energy Networks' ARC project.

Rather than providing single instances of ANM on the distribution network to manage a transmission constraint, the role of the DSO as TSO service provider could become more standardised and widespread.

One model is that TSO treats the GSP as a DNO-owned BMU. Under this model, the DNO would submit bids and offers to the TSO, allowing it to limit the import or export from a GSP at times when the transmission network is constrained. It would then be up to the DNO to use its ANM system to enact the required curtailment using its customers. The DNO would also be responsible for forecasting imports and exports across the GSP. This would represent a major shift in responsibilities, and would require new incentives for the DNOs and new commercial arrangements with customers.

The GSP-as-BMU model could be extended to include other balancing services, such as Short Term Operating Reserve (STOR) allowing the DNO to act as an aggregator for its customers. This would give the TSO access to a large number of non-BMU units and DSR providers to provide balancing services without having to manage them itself.

> **DSO and TSO jointly accessing balancing services**
Rather than having customers bid into independent DSO and TSO balancing mechanisms, balancing could be done in a more coordinated way, with both the TSO and DSO able to see balancing services offered by a given customer. In order to prevent TSO balancing actions from imposing costs on the DSO, the DSO may retain the right to block certain actions or impose a price premium.

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[48] https://www.elexon.co.uk/wp-content/uploads/2015/03/Active-Management-of-Distributed-Generation_March2015.pdf

Glossary of terms

Appendix

A

Appendix A Glossary of terms

AC	Alternating Current
ANM	Active Network Management
ARC	Accelerating Renewable Connections
BM	Balancing Mechanism
BMU	Balancing Mechanism Units
BOA	Bid Offer Acceptance
BSUoS	Balancing Services Use of System
capex	Capital expenditure
CBA	Cost Benefit Analysis
CCCM	Common Connections Charging Methodology
CLASS	Customer Load Active System Services
CLNR	Customer Led Network Revolution
DG	Distributed Generation
DNO	Distribution Network Operator
DSO	Distribution System Operator
DSR	Demand Side Response
DTI	Department of Trade and Industry
DUoS	Distribution Use of System
EAVC	Enhanced Automatic Voltage Control
EES	Electrical Energy Storage
ERP2	Engineering Recommendation P2
ESQCR	Electricity Safety, Quality and Continuity Regulations
FALCON	Flexible Approaches for Low Carbon Optimised Networks
FCL	Fault Current Limiting
FLARE	Fault Level Active Response
FMDA	Failure Modes & Defect Analysis
FPP	Flexible Plug & Play
GB	Great Britain
GPG	Good Practice Guide
GSM	Global System for Mobile communications
GSP	Grid Supply Point
HMI	Human Machine Interface
HV	High Voltage
ICCP	Inter-Control Centre Communications Protocol
ICT	Information and Communications Technology
IEC	International Electrotechnical Commission
IFI	Innovation Funding Incentive
IIS	Interruptions Incentive Scheme
LCL	Low Carbon London
LCNF	Low Carbon Networks Fund
LIFO	Last-In-First-Out
LLCH	Lincolnshire Low Carbon Hub
LTDS	Long Term Development Statement
MVA	Megavolt Ampere
MVAr	Megavolt Ampere reactive
MW	Megawatt
NETS	National Electricity Transmission System
NINES	Northern Isles New Energy Solutions
NMS	Network Management System
NPV	Net Present Value
NOP	Normally Open Point
opex	Operating expenditure
PV	Photovoltaics
RPZ	Registered Power Zone
RTTR	Real Time Thermal Rating
RTU	Remote Terminal Unit
SCADA	Supervisory Control and Data Acquisition
SIM	Scenario Investment Model
SQSS	Security and Quality Supply Standards
STOR	Short Term Operating Reserve
TNUoS	Transmission Network Use of System
TSO	Transmission System Operator

Case studies

Appendix B

Appendix B Case studies

Project Name	Date	DNO	Funding	Project type
Capacity to Customers (C2C)	2012-2015	Electricity North West	LCNF	Innovation

Overview

The C2C trial used ANM to manage the process by which certain customers would have their supply restored following a loss of service. For those customers who signed up to the trial, their consumption was categorised into one of two types:

- > Power for essential uses would be restored as soon as possible
- > Restoration of non-essential power would be delayed for a pre-arranged period of time (e.g. two hours instead of one)

Participation in the C2C trial was available to Industrial and Commercial customers who were already connected to a trial circuit or required a new connection to a trial circuit. Customers were incentivised through reduced connection charges and direct payments in exchange for providing delayed restoration in the event of a power cut or other abnormal occurrences on the HV network.

The use of the methods trialled under C2C are expected to reduce the need for network reinforcement, and to reduce the duration of unplanned outages for all customers.

Customer type	Application	Network implemented	Network served	Status
Demand	Connections & reinforcement deferral	Distribution	Distribution	Trial complete, roll-out ongoing

Further reading

> http://www.enwl.co.uk/c2c

Project Name	Date	Network Operator	Funding	Project type
CLASS	2012-2015	Electricity North West	LCNF	Innovation

Overview

The CLASS project is the trial of an innovative approach to increasing the available capacity on networks through voltage control. Automatic control of the voltage in major substations (i.e. GSPs) can effectively reduce electricity consumption at times of peak demand without reducing the quality or security of supply to customers.

This technique not only helps to meet increasing peak demand whilst avoiding or deferring reinforcement, it also creates some headroom to allow new low carbon generation onto networks.

Customer type	Application	Network implemented	Network served	Status
Demand	Reinforcement deferral	Distribution	Distribution & Transmission	Ongoing

Further reading

> http://www.enwl.co.uk/class/about-class/what-is-class

Appendix B Case studies

Project Name	Date	DNO	Funding	Project type
Customer Led Network Revolution (CLNR)	2011-2014	Northern Powergrid	LCNF	Innovation

Overview

The Customer-Led Network Revolution project assessed the potential of novel smart grid network technologies, new commercial arrangements and customer flexibility solutions to find cost-effective ways to prepare UK electricity networks for the low carbon future.

The ANM system deployed for CLNR is one of the most sophisticated wide area control schemes in operation in Europe - using real-time monitoring inputs, plus state estimation and optimisation rather than relying on pre-programmed rules.
The CLNR project installed and commissioned a range of novel network technologies and undertook approximately 200 trials of the Electrical Energy Storage (EES), Enhanced Automatic Voltage Control (EAVC), Real Time Thermal Rating (RTTR) and Demand Side Response (DSR) interventions deploying the interventions singly and in combinations under the control of the ANM system.

NPG's recommended approach to implementing smart grid systems, based on the findings of this project, is to start relatively simply and increase the complexity as and when required. DNOs can start with relatively simple forms of localised ANM to resolve local issues. Then, more network constraints from more low carbon technologies are seen, DNOs are likely to need to deploy more solutions, whether in isolation or combination (e.g. EES and DSR). As the number of constraints and the number of solutions multiply then so does the need for more sophisticated wide area control systems to join up and add to the localised solutions.

Customer type	Application	Network implemented	Network served	Status
Demand, storage, generation	Connections	Distribution	Distribution	Complete and BaU

Further reading

> http://www.networkrevolution.co.uk/wp-content/uploads/2015/03/CLNR-G026-Project-Closedown-Report-FINAL-V2.pdf

Project Name	Date	Network Operator	Funding	Project type
FALCON	2011-2015	Western Power Distribution	LCNF	Innovation

Overview

WPD's FALCON project encompasses the trial of a number of innovative techniques including dynamic asset ratings (reinforcement deferral), automatic load transfer between 11kV feeders, meshed networks, battery storage for power flow management, DG control using commercial arrangements and demand control using commercial arrangements.

Alongside the technical investigation and development of these techniques is the development of a Scenario Investment Model (SIM). The SIM will allow "future" networks to be modelled with a view to facilitate understanding on how the to use the previously mentioned techniques to solve identifiable problems.

Customer type	Application	Network implemented	Network served	Status
Generation & Demand	Connections & Reinforcement deferral	Distribution	Distribution	Ongoing

Further reading

> http://www.westernpowerinnovation.co.uk/Projects/Falcon.aspx

Appendix B Case studies

Project Name	Date	DNO	Funding	Project type
Flexible Plug & Play (FPP)	2012-2014	UK Power Networks	LCNF	Innovation

Overview

FPP was a 3 year innovation project to trial new technologies and commercial arrangements in order to connect distributed generation (DG), such as wind or solar power, to constrained areas of the electricity distribution network. It delivered greater flexibility in accommodating cheaper and faster DG connections, as well as enabling previously unviable DG schemes to become feasible. It has contracted 16 projects with 8 being operational.

FPP used ANM to offer interruptible connections to a constrained network area on the basis of pro-rata principles of access. A quota was also applied, limiting the total capacity of generation connected within the constrained area to a pre-agreed cap. Once the quota was reached, LIFO was to be applied for future connections.

Customer type	Application	Network implemented	Network served	Status
Generation	Connections	Distribution	Distribution	Complete

Further reading

> http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Flexible-Plug-and-Play-%28FPP%29/

Project Name	Date	DNO	Funding	Project type
Lincolnshire Low Carbon Hub (LLCH)	2012-2015	Western Power Distribution	LCNF	Innovation

Overview

The Low Carbon Hub for East Lincolnshire has been designed to test a variety of new and innovative techniques which will allow new, low carbon generation, to connect to the electricity networks, whilst avoiding the high costs that would normally be associated with more conventional methods (building new overhead lines, installing new underground cables or building new substations). The project received £3m of funding from Ofgem's Low Carbon Networks Fund Tier 2 to demonstrate six alternative techniques: network enhancements, commercial agreements, dynamic voltage control, 33kV active network ring, Flexible AC Transmission System (FACTs) Device and dynamic system ratings.

Of the range of techniques explored through this work, ANM was used to allow WPD to offer "alternative connections"[49]: new innovative commercial arrangements allow generators to take advantage of the spare capacity in the network when it exists and introduces constraints on the output when the capacity does not exist.

Developed as part of the LLCH, Alternative Connections are now being offered alongside conventional solutions. These alternative connections can provide a cost effective way to connect to the distribution network.

Customer type	Application	Network implemented	Network served	Status
Generation	Connections	Distribution	Distribution	Complete

Further reading

> http://www.westernpowerinnovation.co.uk/Projects/Low-Carbon-Hub.aspx

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[49] Synonymous with the term "ANM connections" used in this guide

Appendix B Case studies

Project Name	Date	DNO	Funding	Project type
Low Carbon London	2011-2014	UK Power Networks	LCNF	Innovation

Overview

Low Carbon London (LCL) trialled and demonstrated a broad range of smarter potential approaches to how DNOs may invest and operate in the future. By bringing together leading industry specialists, the project took a multi-party approach emulating what the 2020 or 2030 electricity supply chain (from System Operator to distribution network, distributed generation and supply) may look like.

The LCL trials covered a number of topics, including the Electrification of Heat and Transport, Network Planning and Operation and the role of the future Distribution System Operator (DSO). LCL also trialled and modelled Demand Side Response (DSR) and generation control. The DSR trials included the use of ANM, and the associated Cost Benefit Analysis assessed the benefits of ANM to deliver an enhanced response from Industrial and Commercial customers. LCL also studied the use of ANM to connect additional generation to fault level-constrained parts of the network without the need for reinforcement.

Customer type	Application	Network implemented	Network served	Status
Demand, generation	Connections, Reinforcement deferral	Distribution	Distribution	Complete

Further reading

> http://innovation.ukpowernetworks.co.uk/innovation/en/Projects/tier-2-projects/Low-Carbon-London-(LCL)/

Appendix B Case studies

Project Name	Date	DNO	Funding	Project type
NINES	2011-2016	Scottish and Southern Energy	Special electricity distribution licence conditions	Innovation

Overview

Shetland's ANM system connects and controls the following technologies on the islands:

- > A large scale battery energy storage system at Lerwick Power Station, which will be installed with special capability to enable communication and control of the battery.
- > Advanced energy storage and water heaters in domestic homes that offers flexibility in network demand.
- > Small/Large wind turbines will have communications systems installed to enable issue of control signals and receive status feedback
- > The system will also take into account weather and tidal forecasting information to manage renewable energy generation

The key objectives of the Shetland's Active Network Management trials are:

- > Stabilise Shetland's energy system by managing demand, generation and storage capabilities and monitoring system diagnostics
- > Make energy supply low carbon by allowing the maximum possible amount of renewable generation to be connected thus reducing the amount of fossil fuel consumption
- > Allow local individuals and companies to benefit from the opportunities of establishing renewable generation facilities by accommodating the connection of new small generators on the network
- > Reduce the need to build new power plants and reinforce networks by reducing the difference between minimum and maximum daily demand
- > Make the energy system more reliable by using real time feedback from network monitoring and communication links to detect system health checks
- > Enable customers to participate in energy network management by installing advanced energy and water heaters.
- > Use devices controlled by ANM to manage network frequency

Customer type	Application	Network implemented	Network served	Status
Storage, demand, generation	Connections, Reinforcement deferral	Distribution	Distribution	Ongoing

Further reading

- > http://www.ninessmartgrid.co.uk/our-project/

Appendix B Case studies

Project Name	Date	DNO	Funding	Project type
Orkney RPZ	2004 - ongoing	Scottish and Southern Energy Power Distribution	DTI, IFI, RPZ	Innovation

Overview

Since 2009, Orkney has been home to the UK's first 'smart grid'. Work on the smart grid began in 2004 to address the issue of capacity constraints on the electricity distribution network which were limiting the potential for renewable generation developers to harvest the significant renewable energy resource on the Orkney Isles.

An innovative new Active Network Management (ANM) approach was devised to make better use of the existing network by instructing generators to control their output, in real time, to match the available network capacity. The ANM was switched on in 2009. It allows the power flows at several points on the network to be monitored, and power flows from multiple new renewable generators to be controlled. The technology is based around a central controller, which collects data from 'pinch points' geographically distributed around the network.

The central controller identifies when power flows are approaching the limits of the network power rating and sends instructions to generators to reduce their output in time before problems occur. The system is designed to be fail safe to protect the network if generators do not respond correctly to control signals within specified time limits.

The smart grid has enabled the same amount of renewable generation to be connected to Orkney's distribution network as would have been made possible by conventional network reinforcement at a fraction of the cost.

Customer type	Application	Network implemented	Network served	Status
Generation	Connections	Distribution	Distribution	Ongoing

Further reading

- > https://www.ssepd.co.uk/OrkneySmartGrid/
- > https://www.ssepd.co.uk/WorkArea/DownloadAsset.aspx?id=992

Project Name	Date	Network Operator	Funding	Project type
RESPOND	2015-2019	Electricity North West	LCNF	Innovation

Overview

RESPOND will actively monitor demand and generation on the network, continually assess the fault level and automatically enable one of the commercial or technical innovative mitigation techniques when necessary. The techniques being trialled and demonstrated as part of RESPOND are Adaptive Protection and Is-Limiters and a commercial Fault Current Limiting (FCL) Service. A Fault Level Assessment Tool provides a platform from these a range of innovative fault level mitigation techniques can be adaptively controlled. Customers providing a FCL Service will be rapidly disconnected when a network fault occurs then reconnected within three minutes unless they are without supply due to being within the faulted circuit.

RESPOND will be the first demonstration of near real-time fault level assessment and adaptive mitigation techniques to overcome the fault level challenge faced by DNOs.

Customer type	Application	Network implemented	Network served	Status
Generation & Demand	Connections, Reinforcement deferral	Distribution	Distribution	Ongoing

Further reading

- > http://www.enwl.co.uk/docs/default-source/future-documents/respond-submission-document-redacted-oct-2014.pdf

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MIX
Paper from responsible sources
FSC® C001785

Designed by www.treble-design.co.uk
Printed by Park Communications

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