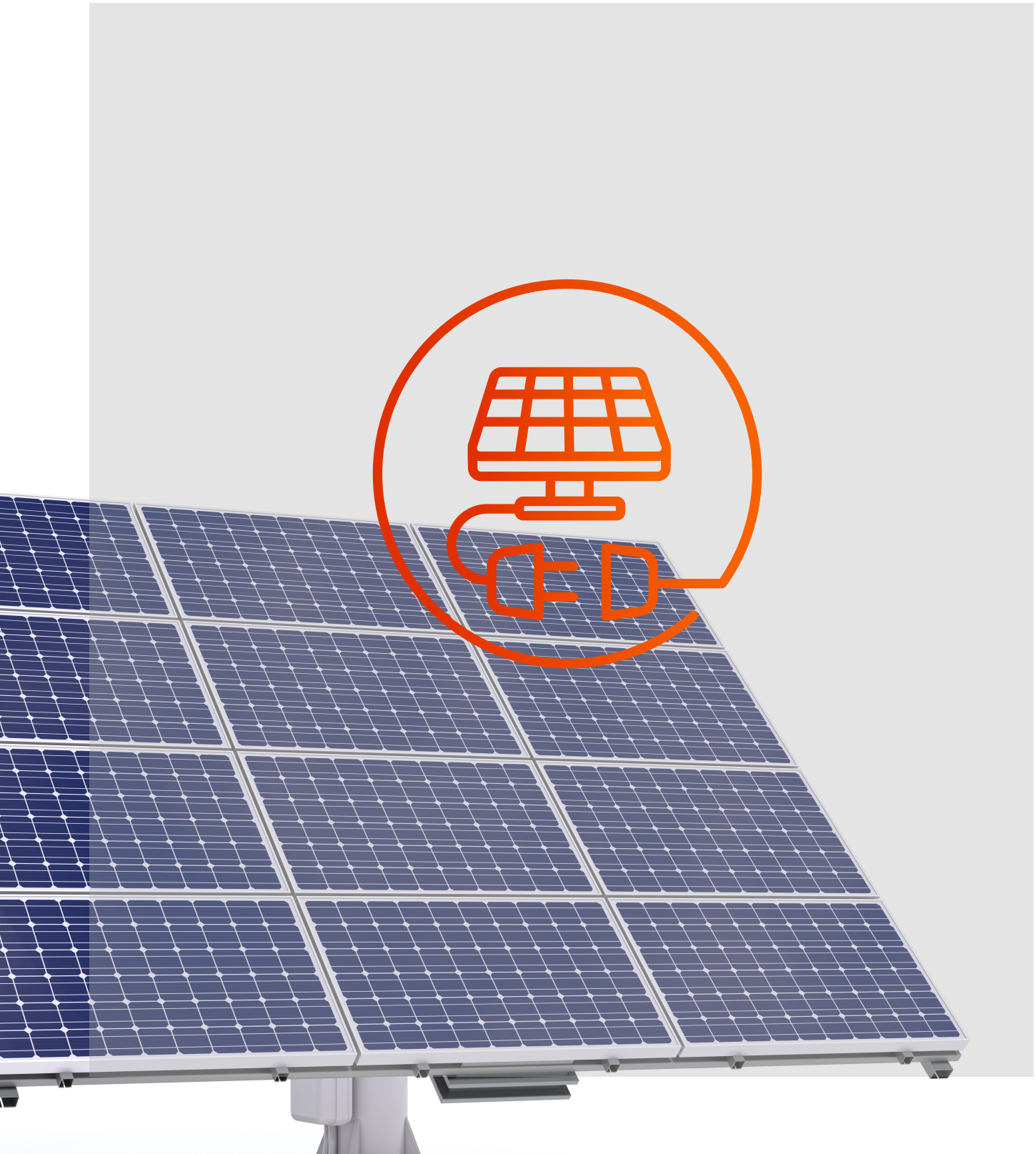
UK Power Networks
Delivering your electricity

# Flexible Connections Customer Guide

December 2021



# Contents



# Glossary of Terms

| | |
|---|---|
| **CCT** | Circuit |
| **DERMS** | Distributed Energy Resources Management System |
| **DIg SILENT Power Factory** | DIgSILENT PowerFactory is the power system analysis software used by UK Power Networks to assess HV and EHV networks. |
| **DGMT** | Distributed Generation Mapping Tool. Visual tool available to UK Power Networks customers which provides network information according to geographical area. In relation to Flexible Connections, the DGMT provides information on estimated curtailment according to technology type and geographical area. The curtailment information that is shown on the DGMT is provided by the network planning team based on the assumption of a new 10 MW customer connecting in a particular constrained area. |
| **DER surgery** | A DER surgery is a meeting between UK Power Network (typically Connections and Network Planning teams) and the customer, which provides an opportunity for the customer to discuss the viability of their scheme before making an application. |
| **DNP3** | Distributed Network Protocol 3. A set of communications protocols used between various types of data acquisition and control equipment. |
| **FDG** | Flexible Distributed Generation. This was the term used to describe customers connected under Active Network Management before the roll-out of the central Active Network Management system. This is now referred to as Flexible Connections. |
| **FPP** | Flexible Plug and Play. FPP was an innovative project by UK Power Networks, completed in December 2014. |
| **GSP** | Grid supply Point |
| **GSoP** | Guaranteed Standard of Performance. Standards set by Ofgem to ensure network operators provide customers a guaranteed good level of service. |
| **GT** | Grid Transformer |
| **LIFO** | Last-In, First-Out. Principle of Access where the last generator in the queue (order based on the application date) is managed first when a constraint trigger is enabled. |
| **MP** | Measurement Point |
| **OM** | Operating Margin. An Operating Margin is a safety margin adopted to account for uncertainties in the assumptions considered. |
| **PoA** | Principle of Access. Principles of Access are rules that determine the allocation of capacity to Flexible Connection applicants when a constraint is triggered. |
| **PoC** | Point of Connection |
| **SF** | Sensitivity Factor |
| **UK Power Networks** | UK Power Networks (Operations) Ltd consists of three electricity distribution networks:<br>• Eastern Power Networks (EPN)<br>• London Power Network (LPN)<br>• South Eastern Power Networks (SPN) |

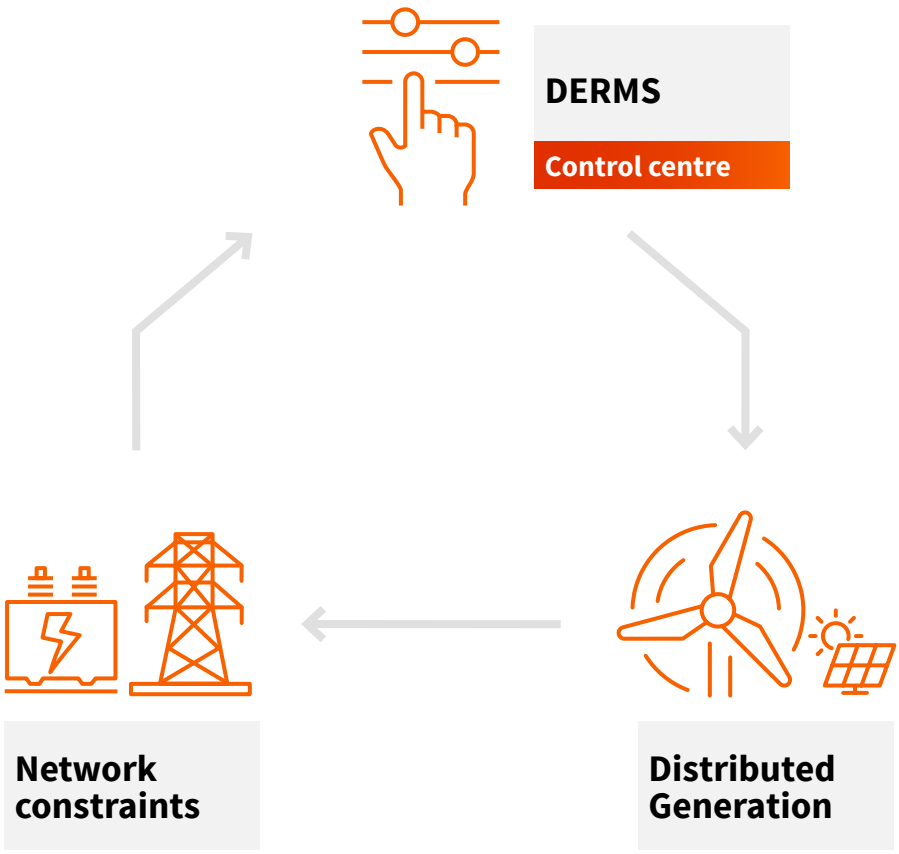
# 1. Introduction to Flexible Connections

## Flexible Connections are one of a number of smart network products that are available to customers in our areas.

Flexible Connections allow customers that want to connect in constrained parts of our network to connect without any associated network reinforcement. This lowers the cost of connection as they do not have to contribute towards the cost of network reinforcement. It also enables customers to connect faster as a physical reinforcement can take a number of years to plan, design and implement.

Flexible Connections are facilitated by our Distributed Energy Resources Management System (DERMS). DERMS is a software application that uses real-time network data and control of Distributed Energy Resources (DERs) to enable more efficient use of network assets. Flexible Connections enable DERs to connect to the network without any associated network reinforcement, by using real-time network data to instruct DER to curtail customers at certain times.

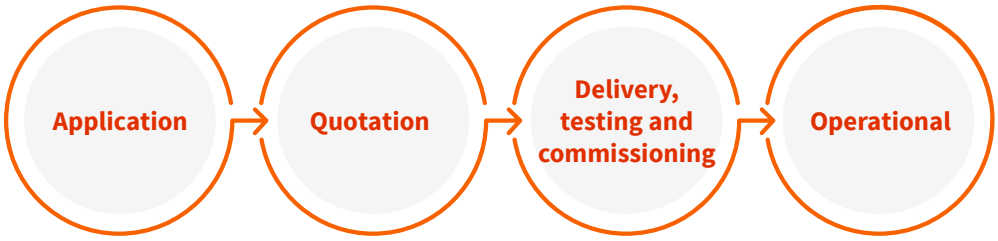
**Figure 1** Flexible Connections high-level overview



# 2. Flexible Connection Customer Journey

This section provides an overview of the customer journey for Flexible Connections in UK Power Networks. The stages of the Flexible Connection customer journey can be divided into four parts as shown below.

**Figure 2** High-Level overview of Flexible Connection Journey




Within each of the stages there are a number of activities. Some of these are activities carried out by the customer, some are carried out by us, and some are joint activities. The following sections will dive into each stage of the Flexible Connection journey in more detail.

## 2.1. Application

We have a number of resources and services available to help customers decide if they want to make a formal application for a Flexible Connection. We'll also support you through the process of applying.

### 2.1.1. Use our DG Mapping Tool

Our Distributed Generation Mapping Tool is a visual tool available to UK Power Networks customers which provides network information according to geographical area. In relation to Flexible Connections, the tool provides information on estimated curtailment according to technology type and geographical area. The curtailment information that is shown on the map of the next page is an example provided by our network planning team. It is based on the annual curtailment of a new 10MW customer of a particular technology type connecting in a specific location.

**Figure 3** Flexible Connection curtailment layer in our DG Mapping Tool

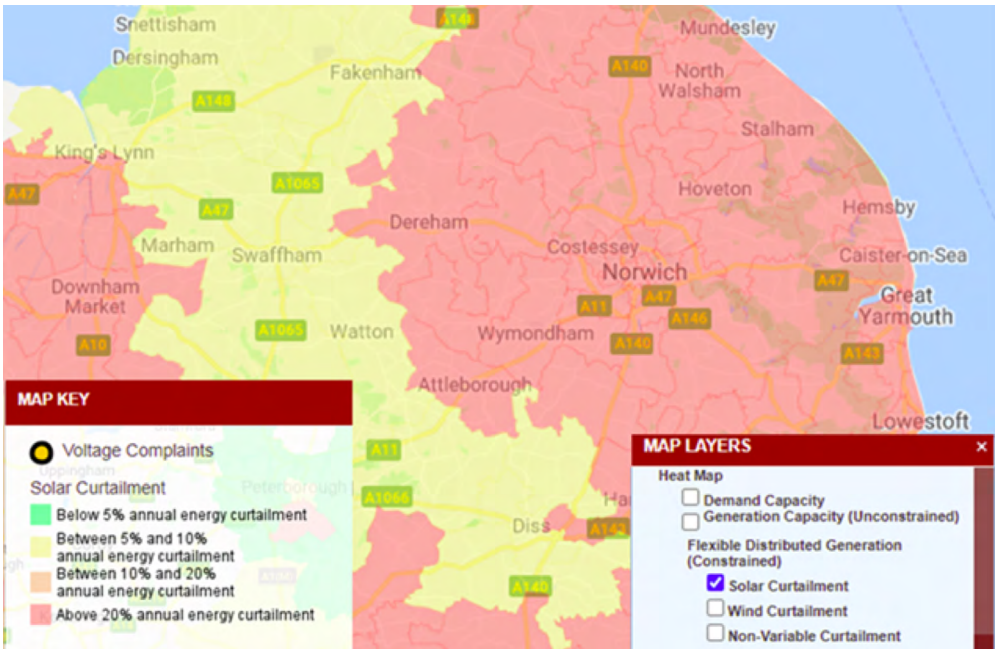



Figure 3 shows an image of the Flexible Connection curtailment layer in our DG Mapping Tool. This example shows that, on the basis of a new 10MW solar customer connecting in the Swaffham area, the high-level estimated curtailment would be in the range of 5-10% annual curtailment.

### 2.1.2. Book a DER Surgery

A DER surgery provides an opportunity for customers to discuss their project with our experts before submitting an application. To book a DER surgery, please send an email to: DG.surgeries@ukpowernetworks.co.uk

### 2.1.3. Request a Free Budget Estimate

You can request a free budget estimate to receive a high-level estimate cost for a Flexible Connection according to your site location, technology and capacity requirements. The budget estimate will also provide an indicative curtailment range for your project. Please note that budget estimates do not reserve any capacity on the network and may vary from the cost and curtailment provided in a future budget estimate and/or formal quotation. To make anapplication please send the details listed below to: connections.gateway@ukpowernetworks.co.uk

- Your name, correspondence address and contact details
- Full site address
- A location plan showing site boundary
- Point of supply location/substation position
- The number of connections you require
- Letter of authority from the landowner
- Technology and capacity
- The type of connection required (e.g. generation or demand with generation)
- The generation type (e.g. wind, solar)
- The required capacity for each connection

### 2.1.4. Formal Quote Application

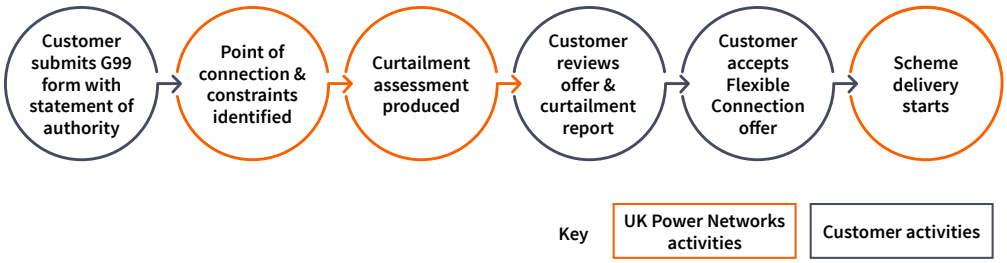
When a customer is ready to make an application for a formal connection offer, they must send the following documents to connections.gateway@ukpowernetworks.co.uk We'll assess your application and get back to you with our Guaranteed Standards of Performance Timescales.

- G99 Standard Application form (page 13 gives the option to indicate you would like to apply for a Flexible Connection)
- Letter of Authority

## 2.2. Quotation

The diagram below shows the journey from making a formal quote application for a Flexible Connection: from receiving a Flexible Connection offer and curtailment report, to accepting the offer. Please refer to Section 3 of this guide for more information on how we produce curtailment reports.

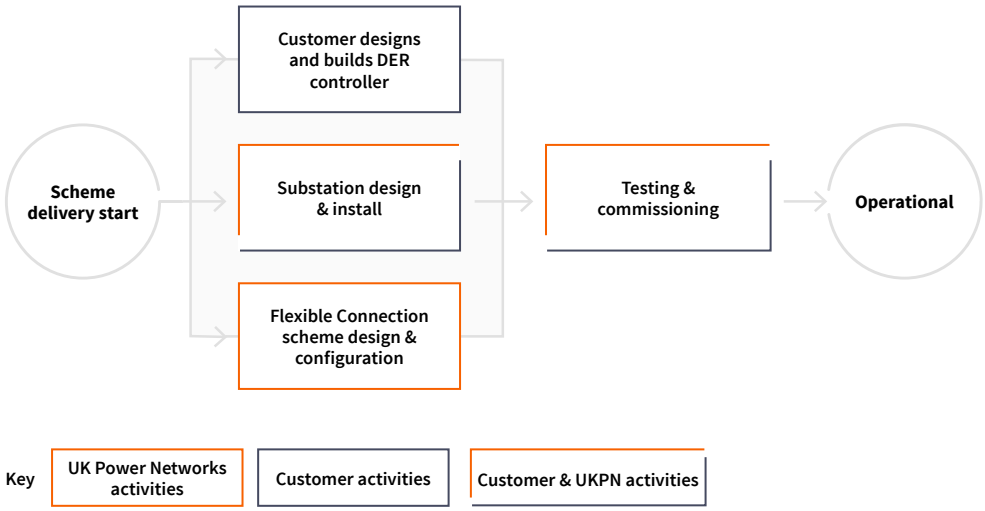
**Figure 4** Flexible Connection Quotation Journey




## 2.3. Delivery, testing and commissioning

The following diagram shows the activities that are involved in the delivery journey for a Flexible Connection.

**Figure 5** Flexible Connection Delivery Journey



As in figure 5, the delivery journey is divided into three key parallel areas of work.

### 1. Customer designs and builds DER Controller

In line with EDS 08-5060 Flexible Connection Requirements standard and EDS-5060a Flexible Connection interface schedule, the customer develops the DER controller that will interface with our RTU. For more information, refer to Section 4 of this guide.

### 2. Substation design and install

The substation is designed in line with EDS 08-5061 Flexible Connection design. For HV substations, there are some equipment and design requirements that are additional to a standard HV generation substation.

### 3. Flexible Connection scheme design and con iguration

The Flexible Connection scheme is designed by the network planning team to be configured into the DERMS platform. There may be new measurement points that need to be installed on the distribution network before the Flexible Connection scheme can be configured and tested in the DERMS platform. Once all activities in each of the parallel areas of work have been completed, the Flexible Connection is ready for testing and commissioning. The testing and commissioning process for a Flexible Connection customer is shown below. Flexible Connection sites cannot export energy to our network until end-to-end commissioning has been completed.

**Figure 6** Flexible Connection testing and commissioning process

#### Packet Capture Simulation

Customer submits simulation of signal exchange between our RTU and their DER controller in line with EDS 08-5060a interface shedule in packet capture format to us for review.

Any issues identified with the simulation will be addressed before processing to bench-testing.

#### Laboratory Bench-Testing

If the simulation results are satisfactory, a date will be scheduled to complete laboratory bench-testing, to prove that the DER controller successfully integrates with the our RTU before progressing to on-site testing.

This usually takes place in one day in our laboratory in London, at least two weeks before on-site testing.

#### Integration Testing

After a successful bench test, the next step is to repeat the signal exchange tests but now on site.

During this test we will also ensure the communications link on site is functioning correctly.

#### Capability Testing

Once the integration testing is complete, the next step is to test the generation capability.

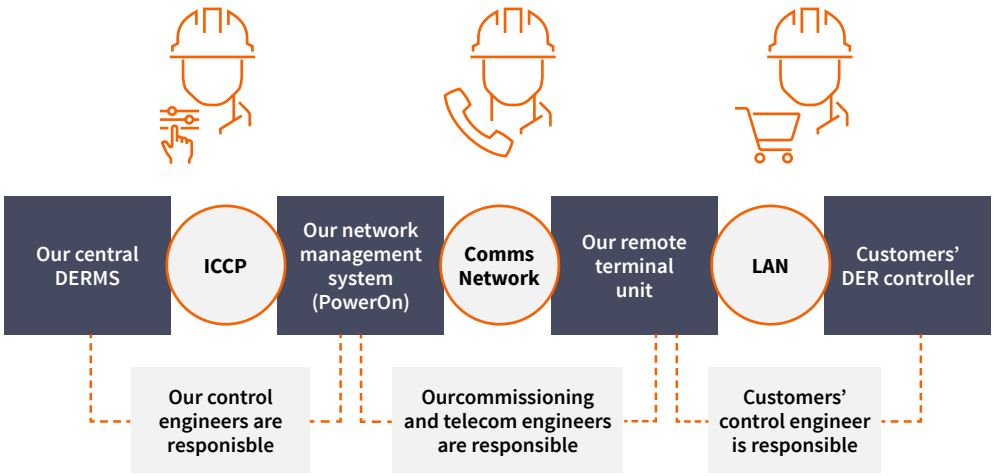
During these tests, the integration of the generator with the DER controller and RTU is tested, including testing the generators ramp-down times are within the limits specified in EDS 08-5060.

#### End-to-end Commissioning

The final step in the testing and commissioning process is end-to-end commissioning, where the integration between all components in the Flexible Connection scheme is tested.

The Flexible Connection is operational following successful end-to-end commissioning.

**Figure 7** Flexible Connection end-to-end commissioning

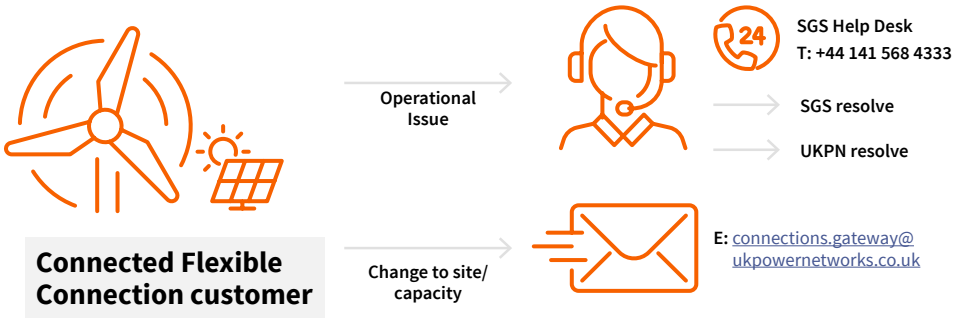



## 2.4. Operational

The diagram below shows the various communication and information channels available once the Flexible Connection is operational. If there is an operational issue, the Smarter Grid Solutions (SGS) Help Desk - our DERMS platform vendor - will be able to help. Depending on the issue, either SGS will be able to resolve it straight away, or it they will get in touch with us.

If there are changes required on site either to equipment or software - or changes in export capacity are required - please contact our Connections Gateway team.

**Figure 8** Flexible Connection communication channels once operational



# 3. Curtailment Assessments

This section outlines our methodology for identifying network constraints and producing a curtailment assessment and report that forms part of a Flexible Connection quotation.

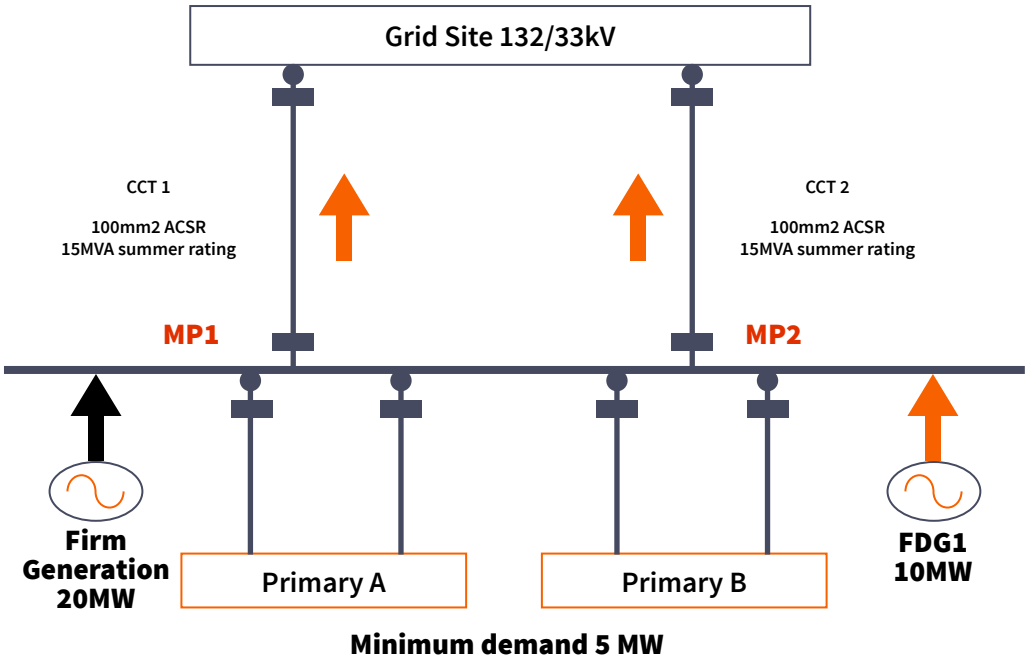
## 3.1. Identifying Constraints

The following are the first steps taken when assessing a Flexible Connection application:

(i) Identify the least capital cost Point of Connection (PoC), in line with all relevant UK Power Networks design standards.

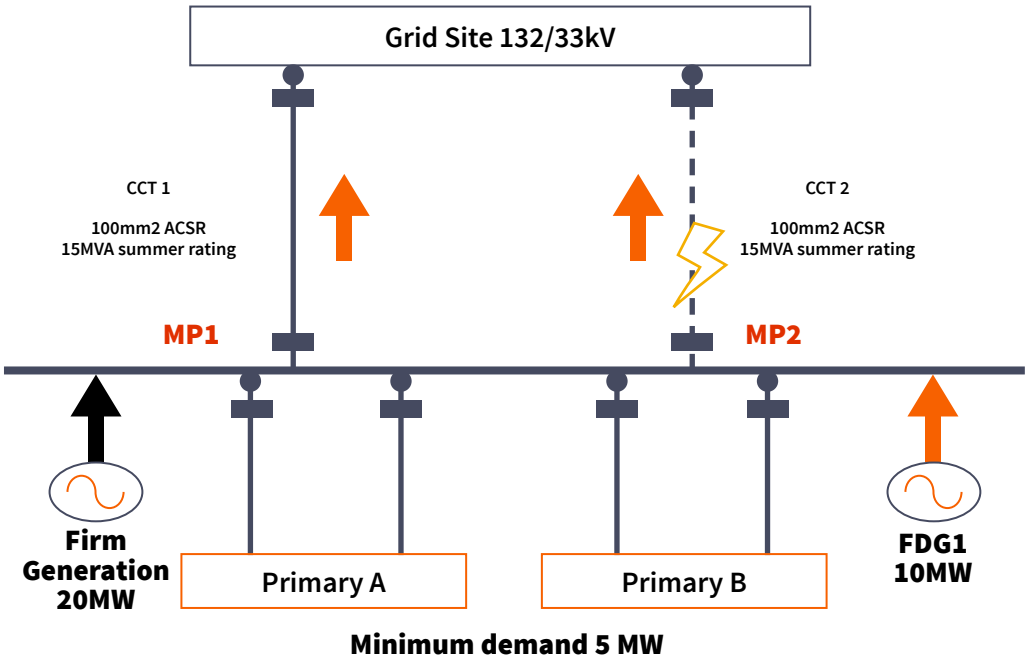
(ii) Run a load flow simulation in a high generation-low load scenario, under intact and outage network conditions, to identify network constraints.
Take the example shown in Figure 9 below. This shows an intact network condition at a substation, where there is a 20MW firm generator and 10MW Flexible Connection (FDG1) connected. The circuits CCT1 and CCT2 can both accommodate 15MVA of capacity toward the grid site. The substation supplies a minimum demand of 5MW.
The maximum generation/minimum load scenario means we consider 25MW export towards the grid site (20MW firm + 10 MW FDG1–5MW minimum demand). In the intact condition, there is sufficient capacity on CCT1 and CCT2 to accommodate the full export of both the firm generator and the Flexible Connection, i.e. no constraints are identified.

**Figure 9** Identifying Constraints in intact (N) conditions




Now consider the scenario shown in Figure 10 below, where an outage has taken CCT2 out of service. Now, under a maximum generation-minimum load scenario, there is 25MW of export that can only be accommodated on CCT1. As CCT1 has a 15MVA rating, there is insufficient capacity on CCT1 to accommodate the full export of the 20MW firm generator and the Flexible Connection FDG1. In this scenario, as FDG1 is a Flexible Connection, it would be fully curtailed to enable 15MW export (20MW firm generation – 5MW minimum load) towards the grid site.

**Figure 10** Identifying constraints in outage (N-1) conditions




CCT1 and CCT2 are active constraints for the Flexible Connection FDG1 under N-1 conditions. MP1 and MP2 are the measurement points on CCT1 and CCT2 which are monitored continuously by the DERMS technology.

## 3.2. Sensitivity Factors

DERMS uses sensitivity factors (SF) to establish a relationship between a constraint location and a generator. Referring back to Figure 9, for example, if FDG1 increases its export 1MW and the power flow across MP1 increases by 0.4MVA, this means that the SF of the generator to that constraint location is +0.4MVA/MW.

Generators that have a sensitivity factor to a constraint location that is below a minimum threshold will not be curtailed in response to the constraint occurring. This is done to reduce curtailment to generators that do not have a material contribution to a constraint.

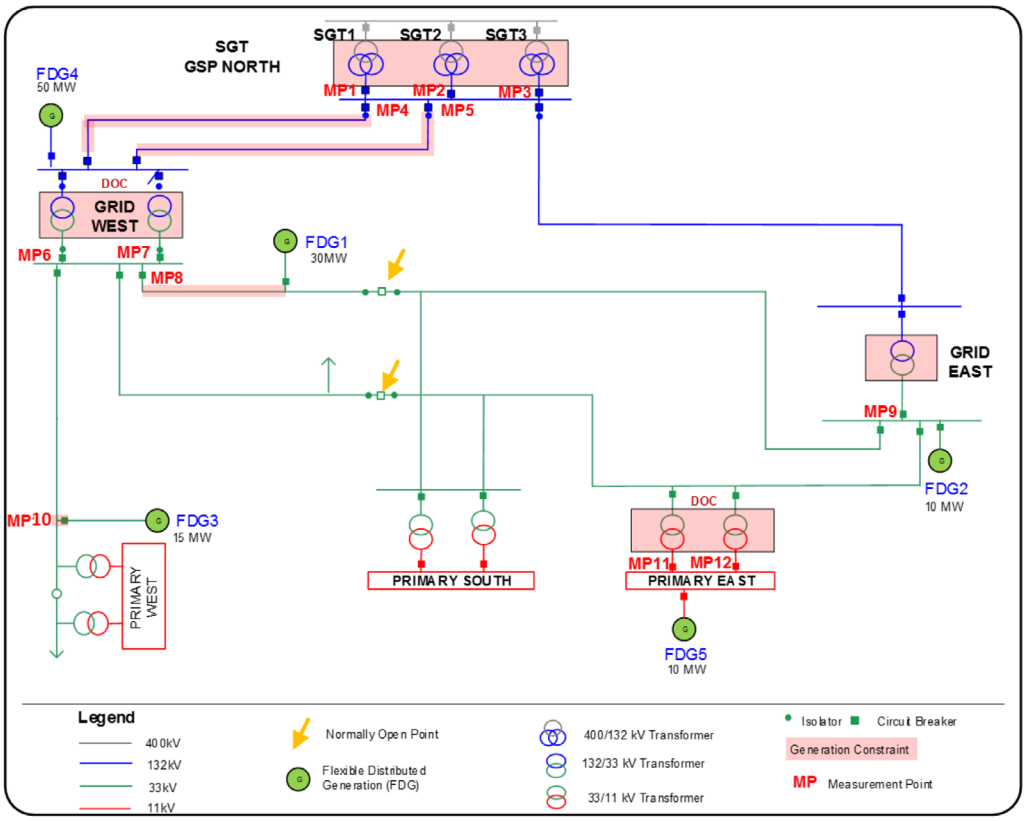
## 3.3. Flexible Connection Schemes

In general, the distribution network is sectionalised by Grid Supply Points (GSPs). A GSP is the boundary point between National Grid and UK Power Networks. In most cases, under normal network running arrangements, the distribution network that is supplied by one GSP is independent from the distribution network that is supplied from another GSP. This makes the GSP boundary the typical boundary for a Flexible Connection scheme. Any Flexible Connection customer connecting within the Flexible Connection scheme boundary will be part of that Flexible Connection scheme. Each Flexible Connection scheme will have an associated LIFO (Last In, First Out) stack.

Flexible Connection schemes can have multiple Flexible Connection customers and multiple constraint locations. However, not all Flexible Connection customers in the scheme will impact all constraint locations.

See Figure 11 as an example of a Flexible Connection scheme. The scheme boundary is the network that, under normal running arrangements, is supplied by “GSP North”.

**Figure 11** Flexible Connection Scheme




There are five Flexible Connection customers connected to this Flexible Connection Scheme: FDG1–FDG5. There are 12 constraint locations, monitored by measurement points MP1–MP12. Assuming FDG1 was the first to make an application for a Flexible Connection offer and FDG5 was the last, the LIFO stack for this Flexible Connection scheme would look as follows:

**Table 1** Example LIFO stack

| Generator | LIFO Position | Status | Technology | Capacity (MW) | Connecting Voltage (kV) | Nearest UKPN Grid/ Primary Substation |
|---|---|---|---|---|---|---|
| FDG1 | 1 | Connected | PV | 30 | 33 | Grid West |
| FDG2 | 2 | Accepted | Gas | 10 | 33 | Grid East |
| FDG3 | 3 | Accepted | Gas | 15 | 33 | Grid West |
| FDG4 | 4 | Live | PV | 50 | 132 | Grid West |
| FDG5 | 5 | Live | Wind | 10 | 11 | Primary East |

In the above example, even though FDG4 is position four in the LIFO stack, it is not subject to as many constraints as FDG1-FDG3 because it is connected at 132kV. FDG1-FDG3 are subject to the constraints at 132kV. but also to the constraints at 33kV. Similarly, under normal running, FDG2 is subject to less constraints than FDG1. In this example, FDG2 is subject Grid East GT and GSP North SGT's constraints, while FDG1 is subject to FDG1–Grid West 33kV CCT, Grid West GT's, Grid West – GSP North 132kV CCT1 and CCT2 and GSP North SGT's constraints.

## 3.4. Preparing and Running the Network Model

To prepare the network model to run a curtailment assessment we'll complete a model by completing the following steps:

**(i)** One year of historical power flow measurements are obtained for all relevant points within the Flexible Connection scheme boundary.

**(ii)** Load/generation profiles for all connected and accepted and live customers in the Flexible Connection scheme boundary are included. Standard generation profiles according to technology type are used where historical data is not available, e.g. newly connected sites or accepted/live Flexible Connection customers. Our standard generation profiles have been devised using industry standards, metering data of existing similar sites and data from manufacturers.

**(iii)** The limits at each constraint location are defined.

**(iv)** The sensitivity factors (SF) of all Flexible Connection customers to each constraint location are calculated.

**(v)** The LIFO position of each Flexible Connection customer is included.

**(vi)** The following standard assumptions are applied to the model:

**Table 2** Standard Modelling assumptions for curtailment assessments

| Variable | Assumption |
|---|---|
| Intact and credible contingency network running arrangements | Interaction between intact and contingency running arrangements defined by planner based on network topology |
| Domestic generation/load growth | Conservative/as per our forecasts |
| Major reinforcement/maintenance schedule (National Grid and UKPN) | Include any major works suspected to impact generation curtailment |

Once all of the above have been built into the network model, the curtailment assessment is ready to be run. We use a DIgSILENT PowerFactory script to run a load flow analysis on the network model for every half hour across a year. The script will calculate how much curtailment is estimated for each Flexible Connection customer according to the assumed network conditions during each half hour period over the course of one year. The output of this analysis is provided to Flexible Connection customers in a curtailment report.

# 4. Flexible Connection Design Requirements

The Flexible Connection Requirements are covered in EDS 08-5060. This standard provides all information on the technical requirements for a Flexible Connection customer. The interface schedule EDS 08-5060a provides the list of signals the Flexible Connection customers need to be able to send/receive from their DER controller to UK Power Networks equipment. You can find both of these documents on our G81 technical library

The following sections will describe some of the key areas of EDS 08-5060 Flexible Connection Requirements standard.

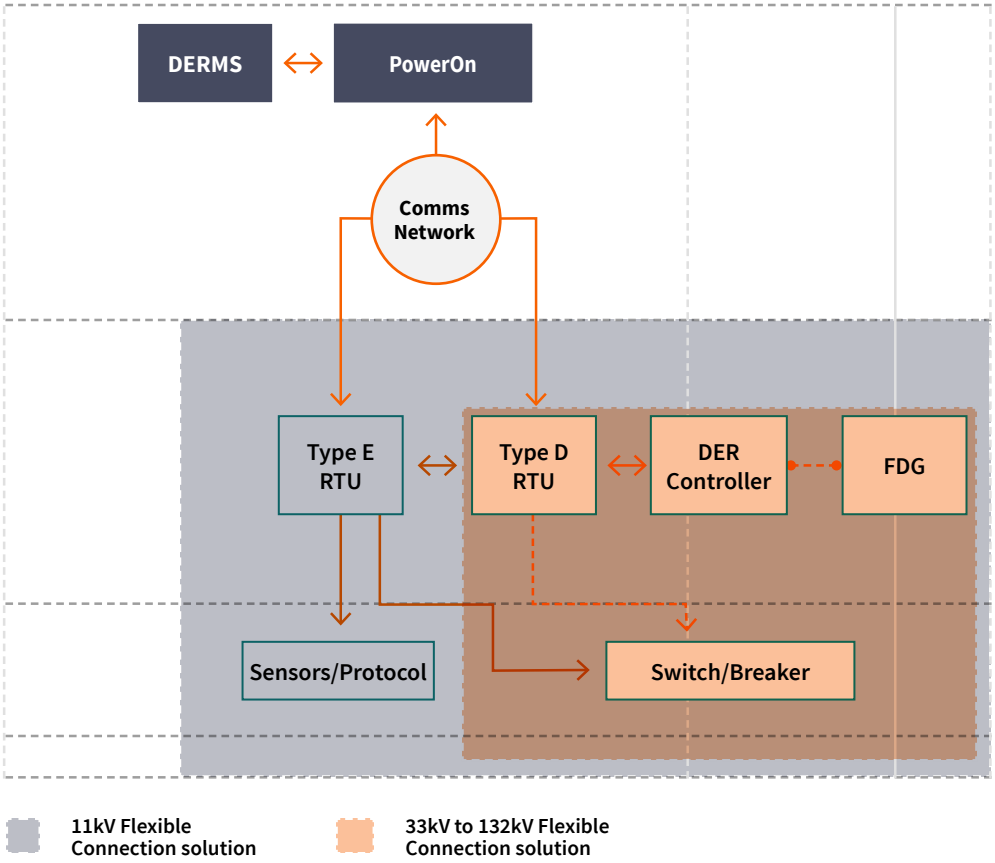
## 4.1. Flexible Connection Control system

The key components of a Flexible Connection control system are:

- DERMS Platform
- Remote Terminal Unit (RTU)
- Communications links
- DER Controller

**Figure 12** Key Components of a Flexible Connection control system

The diagram below shows how both a 11kV Flexible Connection solution and a 33kV to 132kV Flexible Connection solution connect to our network. Customers with a 11kV site require everything in the orange and grey box. Customers with a 33kV to 132kV connection only require everything in the orange box



## 4.2. Generation Ramp-Down Requirement

Flexible Connection customers must support controlled power ramping to prevent distribution system imbalance triggered by abrupt changes in power flows. The table below (as per Section 5.2 in EDS 08-5060) details the maximum ramp-down timeframes of the Flexible Connection customer when a curtailment signal is received from DERMS. These timeframes are in line with ENA G99 requirements.

**Table 3** Generator ramp-down requirements

| EREC G99 types | Generating module capacity | Maximum time allowed to ramp down from full capacity to 0kW |
|---|---|---|
| Type C / D | > = 50000kW | 145 seconds |
| | > = 40000kW and < 50000kW | 125 seconds |
| | > = 30000kW and < 40000kW | 120 seconds |
| | > = 20000kW and < 30000kW | 120 seconds |
| | > = 10000kW and < 20000kW | 120 seconds |
| Type B | > = 5000kW and < 10000kW | 90 seconds |
| | > = 2000kW and < 5000kW | 80 seconds |
| | > = 1000kW and < 2000kW | 60 seconds |
| Type A | > = 500kW and < 1000kW | 45 seconds |
| | > = 200kW and < 500kW | 30 seconds |

Each customers' DER controller must be configured with appropriate ramp down rates to comply with the specified ramp down times and proven as part of the commissioning tests.

## 4.3. Fail-safe actions

The core principle of DERMS is to keep the distribution network within operational limits by sending upper limit kW signals to Flexible Connection customers when a network constraint materialises. Fail-safe actions are configured to operate in order to protect the network in abnormal events.

A fail-safe action will usually instruct the Flexible Connection customer to go to a zero kW set-point until the issue is resolved. An example of such a fail-safe scenario is a loss of communications between the Flexible Connection customers' and our equipment. Another example is in the event of a non-typical outage scenario where a zero-kW set-point is issued to the customer until the impact of the customer to constraints under the non-standard network configuration is calculated.

DERMS can send a signal to open the relevant customer circuit breaker in two scenarios:

**(i)** A Flexible Connection customer fails to comply with the Upper Limit kW set-point which puts other customers and the network at risk.

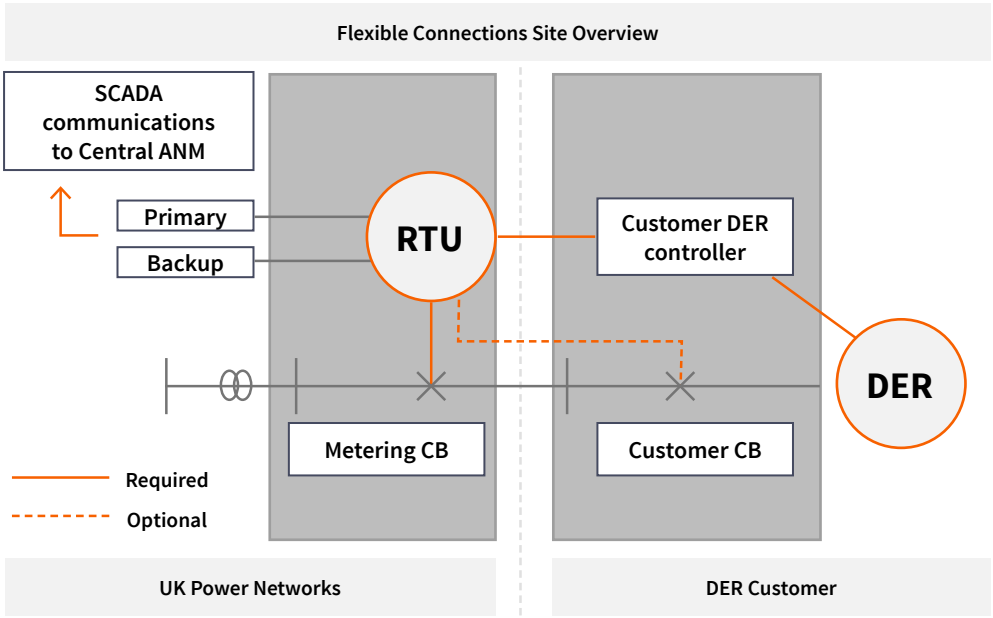
**(ii)** In the event of extreme overload scenarios where a trip signal is issued to the Flexible Connection customer to protect the network.

## 4.4. System Availability

We recommend customers should design their control system architecture with the highest possible level of system availability. Any downtime on the customers' system leading to sustained non-compliance of functional requirements will result in unnecessary curtailment of the Flexible Connection customer.

## 4.5. Flexible Connection site overview

**Figure 13** Flexible Connection Site Overview




DERMS technology requires the ability to disconnect Flexible Connection sites from the distribution network as a fail-safe mechanism under certain abnormal scenarios, as described in Section 4.3.

The default configuration to disconnect Flexible Connection sites as a fail-safe mechanism during abnormal conditions is to open the metering CB. This is shown as a link between the Metering CB and the RTU in Figure 13. However, it is recognised that this can have a considerable impact to sites that have embedded generation, where tripping the metering circuit breaker would also disconnect other potentially significant load services.

Under these arrangements, in the event that the customer CB fails to open following a fail-safe instruction, we reserve the right to open the metering CB as a last resort in order to protect the distribution network.

## 4.6. Communications Protocol and Interface

The communications protocol for the interface between our RTU and the Flexible Connection control system is DNP3 over Transmission Control Protocol/Internet Protocol (TCP/ICP).

**Figure 14** Flexible Connection communications protocol


The IP addressing and communications parameters are covered in EDS 08-5060a Flexible Connection Interface Schedule.

The customer communications interface is shown in Figure 15.

The communications interface for HV connections is shown in Figure 16.

**Figure 15** Customer Communications Interface

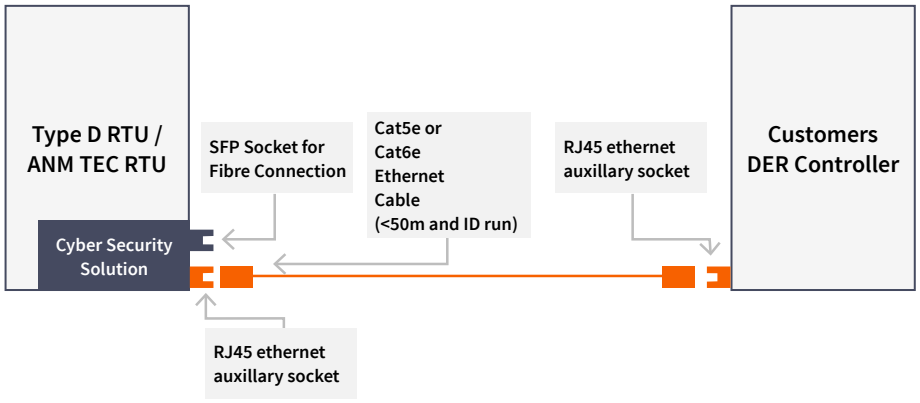
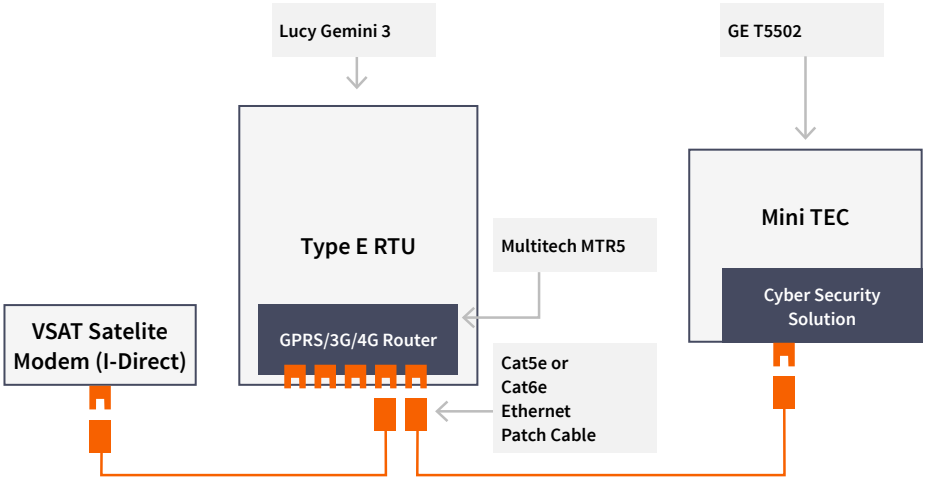



**Figure 16** HV Communications Interface



# 5. Flexible Connection Scheme Design and Configuration

## Section 4.2 describes how Flexible Connection customers form part of an overall Flexible Connection scheme, generally defined by the GSP boundary.

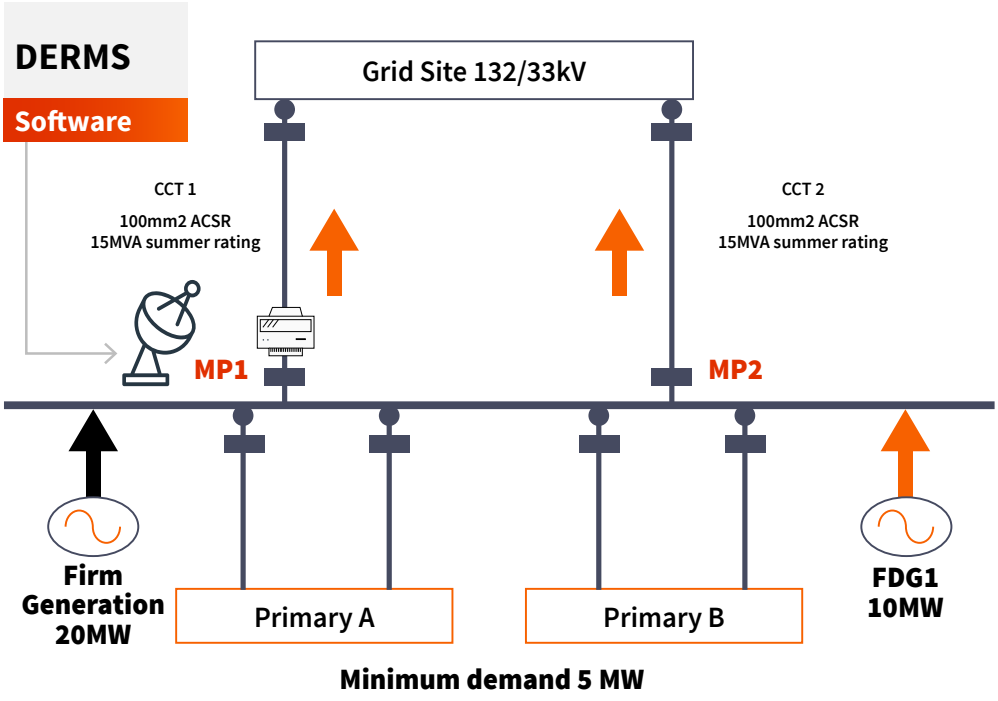
In order for DERMS to be able identify network constraints and send instructions to Flexible Connection customers in real-time, the Flexible Connection scheme must be designed and configured into the DERMS platform, called STRATA.

The Flexible Connection scheme design defines how the site will operate in real-time. It considers the interaction between all Flexible Connection customers in the scheme and the constraint locations under the most common network running arrangements. It takes into account customers' sensitivity factors and maximum ramp-down times (as described in Section 4.2) to set the timers required for the DERMS platform to take various actions.

Part of the Flexible Connection scheme design involves defining the number of measurement points required on the distribution network to monitor constraint locations in real-time. Each measurement point requires system monitoring equipment installed to send power flow measurements from the constraint location back to DERMS.

Figure 17 shows an example of system monitoring equipment in place at constraint location MP1. It continuously monitors the constraint location and sends this data back to DERMS. DERMS will take action if the system monitoring equipment indicates that the constraint limit at that location is breached.

**Figure 17** System monitoring equipment at constraint locations




Before a Flexible Connection scheme can go live, any new system monitoring equipment that is required on the distribution network to monitor constraints must be installed. The timescales for the Flexible Connection scheme to go live can be impacted depending on the level of new system monitoring equipment that needs to be installed on the network. In some cases, significant network outages may be required.

# 6. Useful links and documents

| Item | Link |
|---|---|
| EDS 08-5060 Flexible Connection Requirements | https://g81.ukpowernetworks.co.uk/ |
| EDS 08-5060a Flexible Connection Interface Schedule | https://g81.ukpowernetworks.co.uk/ |
| Flexible Connection webpage | https://www.ukpowernetworks.co.uk/electricity/distribution-energy-resources/flexible-connections |
| DG Mapping Tool | https://dgmap.ukpowernetworks.co.uk/site/?q=user/login |
| DER surgery information | https://www.ukpowernetworks.co.uk/electricity/distribution-energy-resources/der-surgeries |
| G99 Standard Application Form | https://www.energynetworks.org/industry-hub/resource-library/connection-of-power-generating-modules-to-dno-distribution-networks-in-accordance-with-erec-g99.pdf |