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SDRC-11

Development of Novel Commercial Frameworks with Generation and Demand Customers

March 2017

LCN Fund Low Carbon Networks

THE UNIVERSITY OF WARWICK

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Contents

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Glossary

Abbreviation	Term
ANM	Active Network Management
DNO	Distribution Network Operator
FLM	Fault Level Monitor
FCL	Fault Current Limiter
FL	Fault Level
GCP	Generator Constraint Panel
GSP	Grid Supply Point
MVA	Mega Volt Ampere
MW	Mega Watts
NMS	Network Management System
NMC	Network Management Centre
SDRC	Successful Delivery Reward Criteria
WPD	Western Power Distribution

1 Introduction

The Low Carbon Networks Fund (LCNF) Tier-2 project FlexDGrid offers an improved solution to the timely and cost effective integration of customers' generation and demand within Birmingham's urban High Voltage (HV) electricity network. Three separate methods have been identified within FlexDGrid to achieve these objectives:

Method Alpha – An enhanced fault level assessment process;
Method Beta – The real time management of fault level; and
Method Gamma – Integration of fault level mitigation technologies.

This document fulfils the eleventh Successful Delivery Reward Criterion (SDRC) of FlexDGrid "Development of novel commercial frameworks with generation and demand customers" (SDRC-11) by building on the learning gathered from the installation, open loop and closed loop testing of the technologies through integration in to WPD's existing policies, connection agreements and operational procedures.

At the outset of FlexDGrid the aim was to benefit both individual customers looking to connect to an existing fault level constraint network and all customers connected to these networks through the increase in network security. This SDRC focusses on facilitating the connection of additional customers faster and more cost effectively than is currently available through traditional solutions, such as transformer and switchgear replacement. The learning generated through FlexDGrid, specifically the installation and trials of Fault Level Monitors (FLM), has enabled the development of commercial solutions for new and potentially existing customers to further maximise the utilisation of the existing 11kV network.

FlexDGrid was successfully awarded in 2012; this coincided with one of the peak periods of distributed generation installation in the UK. Subsequently, as the innovation project progressed, Western Power Distribution (WPD) was faced with an increasing challenge in trying to accommodate this uptake in new generation connections. In response to this challenge, and taking significant learning from a previous LCN F Tier-2 project Lincolnshire Low Carbon Hub and also the wider industry, the main business introduced a number of 'alternative connection' arrangements that allowed customers to receive an export connection with reduced reinforcement costs and timescales provided they accept periods of reduced output as time of high network stress. These connections range from simplest fixed time of day limitations (Timed Connections), connections that monitor a single constraint point and derive the real-time capacity of the network (Soft-Intertrip Connections) and complex multi-constraint periods calculated in real-time (Active Network Management Connections).

These developments within WPD's business as usual organisation meant that the original aim of SDRC-11, to create novel commercial frameworks and agreements, has been superseded to be the requirement to update and enhance the existing policies, frameworks and agreements created for the three existing alternative connection arrangements to include fault level alternative connections from the substantial learning generated as part of FlexDGrid.

SDRC-11 builds on the work undertaken in SDRC-9 (Closed Loop Tests), described the process and procedure to be used both the benefit all customers connected to the system with a FLM connected, through the ability to parallel the network and further increase their security of supply and individual customers through fault level driven alternative connections.

2 Novel Commercial Framework Development

Based on the principles developed under SDRC-9, for the use of the FLM data and integration with existing WPD operational principles and key commercial documents of fault level constraint network connection opportunities, these have now been updated and are further described in this section.

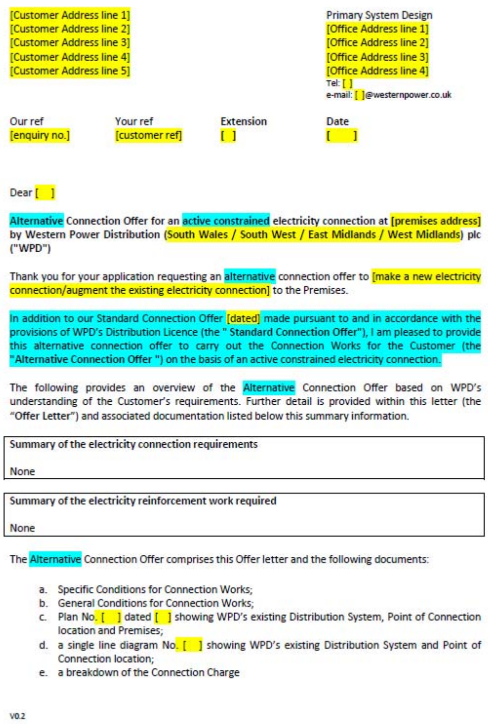
As described above the WPD Alternative Connections process was introduced after the FlexDGrid project had commenced and therefore the documents created, where possible, were written to ensure that fault level was already included, in anticipation of the learning created from FlexDGrid, or suitably worded to enable the fault level constraint element to be easily introduced to the existing wider document.

As with all alternative connections the fault level methodology and agreements ensure that whilst the opportunity for the connecting customer to remain connected to the 11kV network is maximised the safety and security of the wider network is the overriding priority.

Utilising the existing Alternative Connections process meant that the integration of the fault level constraint connection had to be integrated in to one of the three existing options, Timed, Soft-Intertrip of Active Network Management. Each were considered and the selected option was Soft-Intertrip; this was selected as it requires detailed network monitoring in a single, distinct, location and this can be provided by the FLM, which determines the connection capacity relating to fault level in real-time. The learning generated through FlexDGrid and documented in SDRC-8 and 9 clearly demonstrate that the fault level, whilst in some circumstances has a close relationship, cannot be robustly relied upon to be directly correlated with the time of time, excluding Timed connections, and the Active Network Management option would require a level of network interrogation that the FLMs could not provide and furthermore was not required.

2.1 Offer Letter

The existing 'Alternative Connection' offer letter has been reviewed, amended and approved to include scope for issuing offers around fault level constraints; a sample letter is included in Appendix 1.



[Customer Address line 1]
[Customer Address line 2]
[Customer Address line 3]
[Customer Address line 4]
[Customer Address line 5]

Primary System Design
[Office Address line 1]
[Office Address line 2]
[Office Address line 3]
[Office Address line 4]
Tel: [ ]
e-mail: [ ]@westernpower.co.uk

Our ref	Your ref	Extension	Date
[enquiry no.]	[customer ref]	[ ]	[ ]

Dear [ ]

Alternative Connection Offer for an active constrained electricity connection at [premises address] by Western Power Distribution (South Wales / South West / East Midlands / West Midlands) plc ("WPD")

Thank you for your application requesting an alternative connection offer to [make a new electricity connection/augment the existing electricity connection] to the Premises.

In addition to our Standard Connection Offer [dated] made pursuant to and in accordance with the provisions of WPD's Distribution Licence (the " **Standard Connection Offer**"), I am pleased to provide this alternative connection offer to carry out the Connection Works for the Customer (the "**Alternative Connection Offer** ") on the basis of an active constrained electricity connection.

The following provides an overview of the Alternative Connection Offer based on WPD's understanding of the Customer's requirements. Further detail is provided within this letter (the "**Offer Letter**") and associated documentation listed below this summary information.

Summary of the electricity connection requirements
None

Summary of the electricity reinforcement work required
None

The Alternative Connection Offer comprises this Offer letter and the following documents:

a. Specific Conditions for Connection Works;
b. General Conditions for Connection Works;
c. Plan No. [ ] dated [ ] showing WPD's existing Distribution System, Point of Connection location and Premises;
d. a single line diagram No. [ ] showing WPD's existing Distribution System and Point of Connection location;
e. a breakdown of the Connection Charge

V0.2

Figure 2-1 - Sample Offer Letter Front Page

Constraint type agnostic wording was used throughout such as in the opening section:

"This Alternative Connection Offer is made with the intention of providing a lower cost connection, in exchange for the facility for WPD to constraint the connection when required. Where more than one active constrained connection contributes to the same network constraint, when required WPD will constrain these on the basis of 'last in, first off' (LIFO)."

In the 'Conditions Requiring Curtailment" section, again, language was chosen to allow for all manner of constraints to be accommodated, avoiding customer confusion and allowing a simpler transition in to 'Business as Usual'. As an example:

"WPD has used historical load data and profiles for new and existing generators to provide an estimated level of constraints for this connection. For the avoidance of doubt, WPD does not guarantee any level of duration or frequency of curtailment or constraints. The customer is strongly encouraged to conduct their own assessment of the potential curtailments / constraints and risk associated with the alternative connection."

2.2 Connection Agreement

As stated previously the existing Connection Agreement has been updated to provide a specific one for Alternative Connections which states that:

"The Company shall give notice to the Customer whenever it considers it appropriate to do so, requesting the Customer to restrict the generator export or disconnect the generator from the Distribution System when abnormal running arrangements are in force. The Customer shall at its own expense comply with any notice given by the Company."

On review of the document to assess its suitability in this instance it was found that this statement was appropriate for use for the purposes of Fault Level Soft-Intertrip and no further additions were required.

It was felt throughout that amendments and omissions to existing documents should, where possible, be minimal to reduce and change in process and / or procedure experienced by the connecting customer.

Appendix 2 contains a sample connection agreement.

2.3 Curtailment Study

Before accepting an alternative connection over a conventional connection the customer must first consider the potential risk of curtailment against savings in reinforcement costs and timescales. For the current alternative connection suite a curtailment study is undertaken for every application and the results included within the alternative connection offer. The curtailment study models what impact the proposed connection will have on the existing network and calculates how often the new connection will potentially need to be curtailed around significant "pinch points" to avoid large scale reinforcement. The study gives an indication of both times of curtailment together with anticipated energy curtailed. It is stressed that the study is an indication only on historical data and the customer must undertake their own due diligence in order to satisfy themselves of the risk, including any future external factors that may change.

WPD has already undertaken work to ensure a consistent approach to curtailment across DNOs (For Voltage & Thermal issues) by working with the Engineering Network Association (ENA) on its curtailment consultation, from which WPD produced a draft methodology (As Shown in Appendix 3). To ensure consistency it has been ensure that any Fault Level curtailment assessment presentation will fit these existing guidelines.

Curtailment Calculation Methodology

WPD has developed a number of approaches for in house curtailment calculation as their alternative connection suite has expanded. Drawing on this development experience a repeatable approach to curtailment was established for Fault Level issues.

The general principle behind a fault level curtailment study is to identify under what circumstances a generator will need to be curtailed and how often these events occur. It is considered, due to the existing operational regime of the 11kV in Birmingham, whereby two elements of the network run in split configuration that a fault level issue would arise from connecting these two elements of network in parallel with an additional generator or load connected. Therefore, for fault level constraints this study can be achieved by using power system modelling software to run iterative studies in which the fault level of the 11kV busbar with a FLM connected is gradually increased, each time the effect on the parallel fault level is also assessed. A point is reached where the proposed 'Fault Level Soft-Intertrip' connected generators will need to be disconnected, or some other mitigating action undertaken, in order to undertake a network parallel without overstressing the switchgear.

Curtailment Study Layout

The layout of the curtailment study largely falls in line with existing offerings as detailed above. The most significant change is the how the curtailment results are presented which required a graph to be replaced by a number of tables in order to concisely convey the required information to the customer. The reason for this is that the curtailment experienced under fault level constraints does not lend itself to graphical representation due to its 'digital' nature. I.e. the generator is either on or off in periods defined by the maintenance frequency. Appendix 4 shows an example curtailment study.

Cost and Apportionment

Whilst avoiding fault level reinforcement costs and associated timescales the customer will incur costs associated with the installation of the generator constraint panels, communications between the network management system and an apportioned contribution towards the installation of the FLM. The total one–off cost to the customer in this instance would be £91,000.

By means of a comparison a switchgear change to accommodate the increase in fault level and allow a 'conventional' connection would cost the customer in excess of £300,000 and take a minimum of 48 months to complete.

A new methodology for calculating the apportioned cost associated with the customer's FLM use was established. The calculation involves using the power system modelling software to establish the maximum generation that could be connected under the existing arrangement before the equipment ratings are exceeded under normal, split, running. This calculation was used because once the equipment ratings are reached the area is now sterilised and the Soft-Intertrip solution would result in no further benefit. This maximum generation value is then taken as the maximum theoretical capacity for the purposes of the apportionment calculation.

2.4 Policy Documents

In parallel with the commercial frameworks the necessary changes to internal policies and procedures were undertaken. As discussed previously the policies and other documents were constructed to ensure that the minimal amount of changes are required to incorporate fault level constraint connection opportunities. Below is an overview of the policy changes (the full policies were included as appendices to SDRC-9).

Relating to Soft-Intertrip Schemes – Standard Technique OC9E
Standard technique OC9E sets out the process and procedures followed by the Control Centres when creating and managing Soft-Intertrip Control Schemes. This policy was updated to include the principles for managing Fault Levels using the existing WPD Soft-Intertrip philosophy.

Relating to Managing Processes for Alternative Connections – Standard Technique SD10/2
Standard Technique SD10/2 covers policy for managing processes directly relating to alternative connections. The policy was updated to include the ‘Smart Mitigation’ available around Fault Level Constraints i.e. Introduce Fault Level Soft Intertrip Scheme. The table containing location suitability for alternative connections has also been updated to cover Soft-Intertrip (Fault Level) and is shown in Figure 2-2.

This is contained in Appendix 5.

11.0 USAGE OF ALTERNATIVE CONNECTIONS

	Timed	Soft-Intertrip	Soft-Intertrip (Fault Level)	ANM	Export Limiting
LV	X	X		X	X
11kV	X	X	X	X	X
33kV	-	X		X	X
132kV	-	X		X	X
Scheme Capacity per Constraint	<20% of Installed PV Capacity	3	Unlimited	Unlimited	As per ST:SD1E
Issued by:	(11kV) Planner	(11kV) Planner/ PSD	(11kV) Planner	PSD	(11kV) Planner/ PSD
Connection Size:	≤1MW	>250kVA	>250kVA	>250kVA	Any
Location:	All Areas	All Non-Complex Networks	See 11.1	As per Innovation Strategy	All Areas

11.1 Soft Intertrip (Fault Level) is currently available on a limited number of busbar sections at the following Primary substations;

- Bartley Green
- Bournville
- Shirley
- Chad Valley
- Chester Street

Figure 2-2: Alternative Connection Availability

Relating to the Process of Offering a Soft-Intertrip Connection – Standard Technique: SD10B
Standard Technique SD10B which relates to the process for offering a Soft-Intertrip Connection has been reviewed and found not to require any updates for the provision of the system around Fault Level Constraints.

Application of Generator Constraint Panels – Standard Technique: TP18A
Standard Technique TP18A which relates to the Application of Generator Constraint panels was produced during the lifetime of FlexDGrid and therefore considered the future requirements of Fault Level response functionality and therefore did not require any further updates.

3 Commercial Framework - Trial Connection

In order to trial and refine the updated commercial documents and operational policies a trial customer was recruited and the process and trial is described in detail below.

3.1 Customer Identification

In order to allow for the most realistic development and analysis of the policies and procedures an initial piece of work was undertaken to identify potential 'real-world' sites facing connection limitations caused by fault level issues. The project team engaged with local network planners in each of the FlexDGrid substation areas and using their local knowledge and currently active generator quotations, identified two schemes, currently in the quotation stage, which could potentially have the connection times and costs improved through the application of a FLM Soft-Intertrip arrangement. On further investigation these sites were deemed to be unsuitable for trials as they were yet to commit to a connection and the on-site build timescales would not have suited the wider FlexDGrid project timescales.

Subsequently, a network planner identified an existing connection that could potentially benefit from participation in the FlexDGrid trial, although through an application which was not originally envisaged. The customer in question is a large recycling business with existing on-site generation. When these generating units were originally installed in the 1990s it was identified that a fault current limitation device, Is Limiter, would need be installed on-site to reduce the fault contribution and prevent the switchgear at Nechells West primary substation becoming overstressed. These Is limiters had now reached the end of their useful life and now required replacement.

The WPD Primary Design team had approached by the customer to establish if any network changes had taken place which could have impacted the connection meaning that a n Is Limiter at the site would no longer be required. After network analysis the customer was advised that an Is Limiter would be required at the site. Shortly after the customer had placed an order for a new limiting device the project team approached them about being part of the FlexDGrid. The intention was to negate the need for the requirement of an Is Limiter by using the FLM values at Nechells West to disconnect the customers generation at times of high fault level infeed to avoid overstressing the switchgear.

3.2 Customer Engagement

The customer had committed to the order of the Is Limiter and was, in the immediate future, keen to keep a secure and firm generation connection, however, the customer was interested in taking part in the trial and simulating the effect on the their business had our proposal been implemented in place of a traditional network solution.

In March 2016 an initial site visit was undertaken with the customer to fully understand their site operation and the fault level limitations placed on them. From the meeting it was established that the customer had three 'large' generators, two Combined Heat and Power (CHP) plants and one gas generator, on site which could potentially be controlled. However, the site itself is self-sufficient in both electricity and steam from the two large CHP units and it would be detrimental to production if total steam production was ceased, even temporarily. With that in mind, the decision was made to pursue with the trial using the 800MVA gas generator and the 4.7MVA CHP Unit.

3.3 Customer Proposal

Following initial engagement with the customer a detailed proposal was produced and presented, which consisted of the elements detailed in the sections below.

Curtailment Study

Table 3-1 documents the output from the detailed curtailment study for the customer. The table shows the FLM values at which mitigating actions are required. As can be seen the mitigating actions are escalating in severity and include wider network alterations.

FLM Value (kA)	Mitigating Actions
≥12.705	No Acceptable Mitigating Actions Available
12.190 to 12.704	800kVA Gas Generator Disconnected 4.7MVA CHP Disconnected Bus-Section Z-Y Open
10.675 to 12.189	4.7MVA CHP Disconnected Bus-Section Z-Y Open
≤10.674	Bus-Section Z-Y Open

Table 3-1: Mitigating Actions

Using these kA values, the historic FLM data can be interrogated to assess how often the values had been breached to give a view of how often this would likely happen. Historic switching schedules are also reviewed for instances where the modelled switching arrangement would take place to give a view of frequency. This frequency of operation together with the probability of the FLM measured being above the set threshold can be presented to the customer for review. Table 3-2 shows the output included in the curtailment report. The purpose of the table is to present the any potential impacts on their operation as concisely as possible.

Mitigating Action	Av. No. of Actions per Year	Average Length of Action (Minutes)	Typical Times When Action May be Required	
800kVA Gas Generator Disconnected	1.16	3	9.30am	2.30pm to 4.30pm
4.7MVA CHP Disconnected	2.52			

Table 3-2: Effect on Customer Plant

"Mitigating Action" details what the customer would be required to do. In this instance it would be to disconnect some of their generating plant.

"Av. No. of Actions per Year" is a value calculated using the frequency of switching operations requiring curtailment together with the probability of the FLM value being high enough to require action. This is the reason why this is not an integer.

"Average Length of Action (Minutes)" is the typical duration of a disconnection in this instance. For an occurrence such as this this value represents the time taken to make and break the significant parallel.

"Typical Times When Action May be required" gives an idea of the times of day the disconnection will typically be required. As, in this instance, the issue is experienced during maintenance operations the parallel network configurations are usually undertaken at either end of the working day. This information is included as the customer may have more critical times than others during their internal production/operation.

The final part of the study is to determine the cost apportionment of the works to be undertaken to facilitate a fault level Soft-Intertrip scheme. These costs for future schemes would centre on the installation of an FLM and a Generator Constraint Panel (GCP) at the customer's site to manage the constraint operations. In this example the maximum theoretical capacity is an additional 6.5kA. As the customer in this instance is connecting an additional 2.2kA, through their generation output, then the total apportioned constraint cost is:

$$2.2/6.5 = 0.33 \text{ (33\% of full cost)}$$

Any subsequent connected generation connected in that area under the Soft-Intertrip scheme would need to pay their appropriate apportionment contribution based on their fault level infeed value. It should be noted that every subsequent customer will receive more onerous constraint conditions as they fall further down the priority queue.

Generator Constraint Panel

In order to provide the necessary generator at the site a 'Generator Constraint Panel' was installed at site. See Figure 3-2: GCP Installed for completed install.

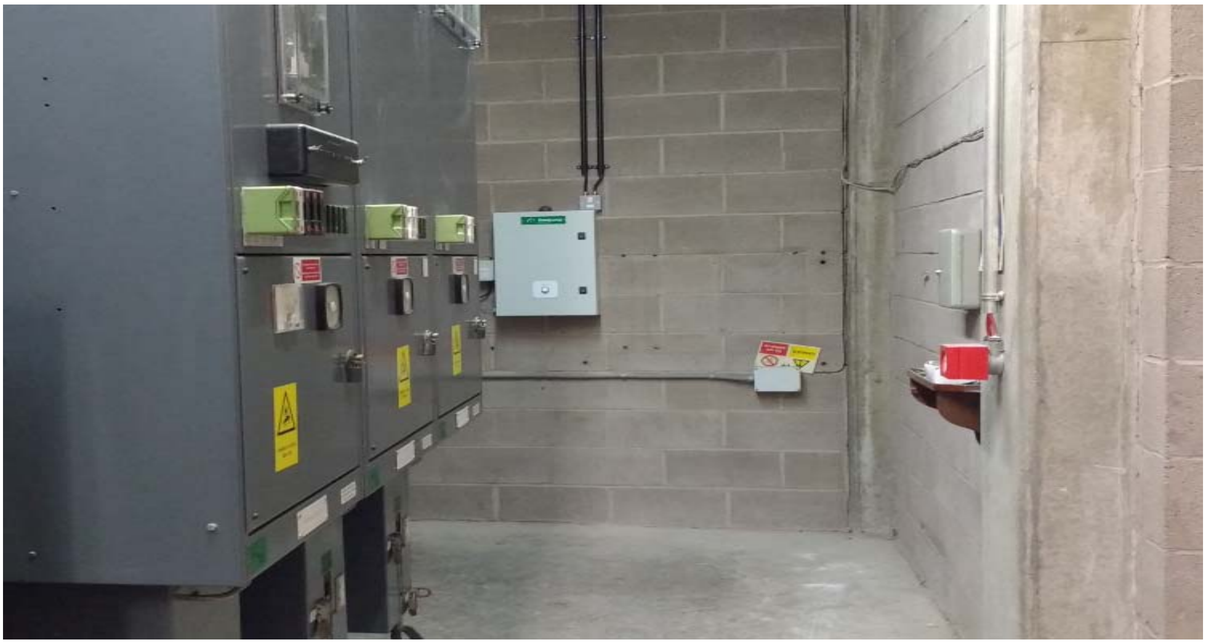


Figure 3-1: GCP Before

Figure 3-2: GCP Installed

As an Is Limiter was in place and to ensure that the generators were not unnecessarily interrupted the final hard wiring between the GCP and the customers generator controllers was not undertaken. However, the panels do display Stage 1 and Stage 2 indications to show when a curtailment instruction has been initiated.

An Ultra High Frequency (UHF) antenna was installed at the site to allow communication between the GCP panel and the Network Management System (NMS). The communication route utilised the existing infrastructure at Nechells West primary substation.

Figure 3-3: GCP Antenna

Once the GCP panel had been commissioned the GCP icon was placed within the NMS diagram to allow constraint signals to be sent on demand, as prescribed in Table 3-1.

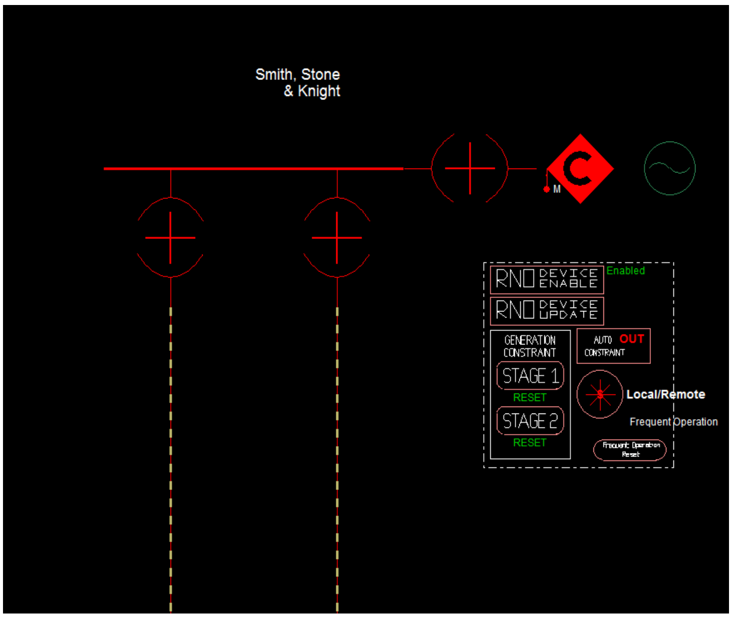


Figure 3-4: Network Management System GCP Interface

Operation Results

Since the installation of the GCP at the customers site there had not been any switching operations undertaken with a requirement to initiate a curtailment of the connected generators. Therefore, in order to full test the operation of the wider system, a trial operation was undertaken on the 17th of February with the resultant switching log displaying the generator constraint operation and reset shown in Figure 3-5.

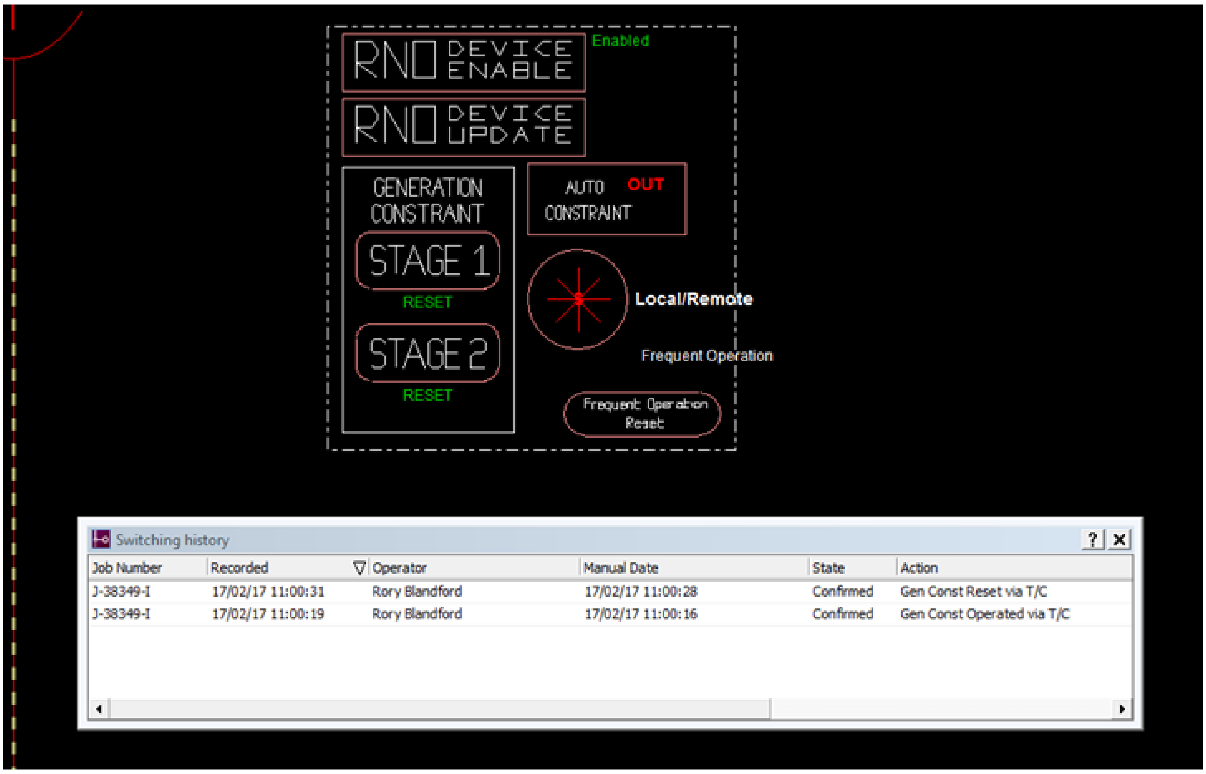


Figure 3-5: Action Network Management System Curtailment Requests

4 Design Decisions - Trialled Technologies

Key decisions were considered when producing the Fault Level Soft-Intertrip methodology, both technical and commercial considerations. These are described in detail below.

4.1 Generator Constraint Panel

Figure 4-1: Generator Constraint Panel

The Generator Constraint has been developed by WPD and evolved to meet the growing need for a means of WPD to issue signals to customers to change their import or export due to constraints on the network. The GCP can issue import/export set-points to the customer either derived locally or from the central NMS system; it then monitors the customer to ensure that these set points are met in a timely manner. If the customer is non-responsive to instructions from the GCP then the customer is disconnected. By installing the GCP panel in this scenario the customer shall receive an instruction to disconnect via the GCP panel only.

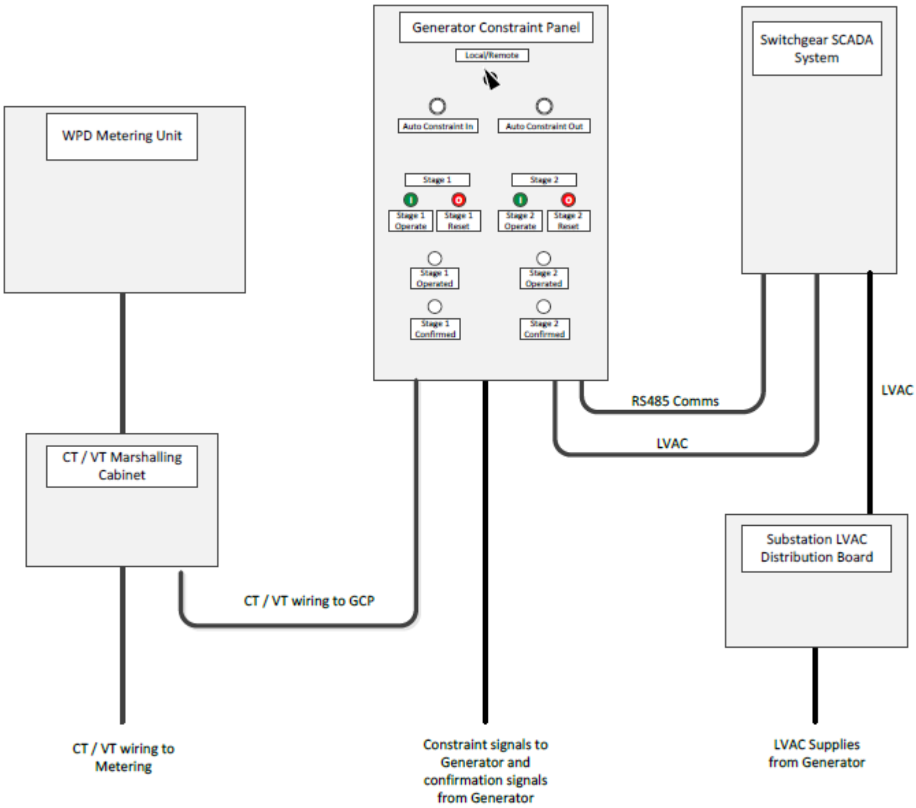


Figure 4-2: Generator Constraint Panel Typical Arrangement

Using bespoke threshold settings within the GCP no additional development was required for it to function under fault level Soft-Intertrip preventing any additional costs. It also meant when producing offers the established business as usual hardware and installation costs could be used.

4.2 Decision System Optioneering

In order to ensure consistency for customers with other offerings available from WPD it was ensured that any new commercial arrangements align with principles previously established. Through an assessment of the existing ‘Alternative Connection’ offerings Active Network Management and Soft-Intertrip where identified as having potential to incorporate the ‘Fault Level’ constraints.

Active Network Management

WPD has a well-established Active Network Management (ANM) roll-out plan and associated internal policies and procedures, because of this initial effort to develop novel commercial contracts used existing ANM systems as a starting point.

ANM is a general term for systems that can manage generation and load for specific purposes; generally to keep system parameters within predetermined limits. Real-time or near real-time measurements are used with a model of the system to determine the control signals that need to be sent to users and generators. The system allows control even over the most complex networks.

Existing ANM service providers were approached to provide an outline for an ANM solution in the Birmingham area utilising the FLM outputs that would facilitate quicker and cheaper connections of demand and generators around fault level constraints. A number of service providers responded with methodologies similar to their existing offerings but utilising the FLM input as a measurement analogue which would be used to calculate what, if any, customer installations need curtailing to keep the system within safe fault level limits.

A number of factors prevented the proposed solutions being taken up. The first issue being cost, which would have made connections associated with establishing an ANM scheme prohibitively expensive. The second issue is that with only one FLM installed at each site the system would need to rely on modelled data regarding the fault level of system being paralleled on to. This makes having a fully automated ANM system very difficult and would need a control engineer in the loop to have the final say on the appropriateness of the action. These conclusions naturally led to an investigation in to the integration of FLM in to WPD Soft-Intertrip solutions.

Soft Intertrip

Soft-Intertrip connections are a current WPD offering on networks that are constrained due to a single upstream asset requiring reinforcement, or a single limit being infringed under certain conditions. Through monitoring these conditions, further capacity can be released when these limits or assets are within normal operating parameters.

Once installed, the on-site Generator Constraint Panel will provide two normally open contacts for the customer's control system to monitor; Stage 1 and Stage 2. When both sets are open, the connection will be free of constraints. The levels of curtailment corresponding to the operation of the Stage 1 and Stage 2 contacts will be defined at the planning stage.

Fault level constraints fit well with the existing Soft-Intertrip philosophy and the existing generator constraint panel can be used to control customer's generators with only a change to the measured thresholds and timers.

The only significant difference between a thermal Soft-Intertrip scheme and a fault level scheme is that no network management sequence switching scheme is required for a fault level application. The reason for this is because the control engineer must still have the final decision before a parallel is made because the fault level on the network on to which the parallel is being made is unknown.

4.3 Artificial Disturbance vs. Natural Disturbance Data

As discussed previously within the project two calculated fault level values are available that are calculated via two alternative means, the natural disturbance and the artificial disturbance.

One set of the Outram Research PM7000 power quality analysers detect voltage and current from Natural Disturbances (ND), such as tap change operations, on the network from which peak make and rms break fault levels are estimated. This gives the infeed (upstream) 11kV fault levels through the 132/11kV transformers. The frequency at which these NDs occur is not controlled; larger NDs give rise to larger confidences in the estimated data.

Another set of dedicated PM7000 power quality analysers detect Artificial Disturbances (AD) introduced by an S&C Electric Company IntelliRupter® PulseCloser® Fault Interrupters that are connected to a particular 11kV busbar at each of the primary substations. The peak make fault current can then be calculated and the rms break fault currents estimated when the S&C device operates for 5ms.

Whilst measurable natural disturbances occur more frequently, approximately every six minutes, they only present part of the fault level contribution and also were deemed to be less accurate as the disturbing event is not well defined, unlike the artificial disturbance introduced. Figure 4-3 gives an indication of the difference in data values captured using ND and AD.

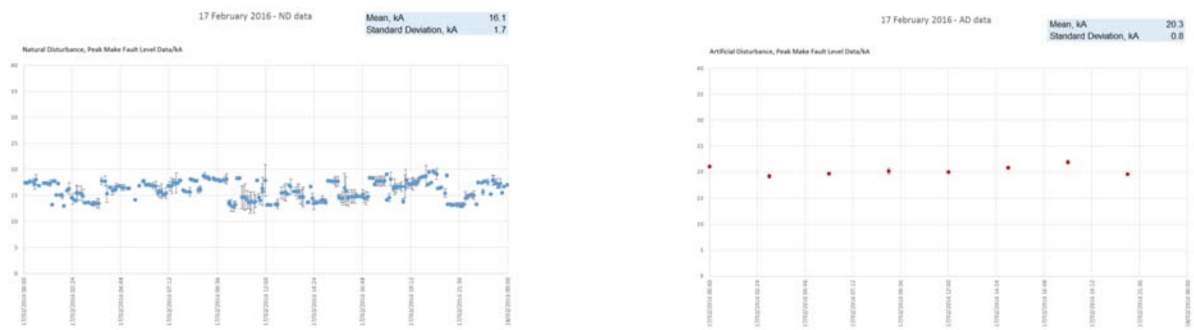


Figure 4-3: Peak Make ND Vs AD

For these reasons only artificial disturbance data is displayed for use in the scheme.

4.4 Fault Level Soft-Intertrip without FLM Input Data

It was determined from the curtailment analysis that the customer is only at risk of disconnection during periods of planned maintenance. As these maintenances are generally part of a multi-year programme they can be easily predicted, are reasonably infrequent and the actual curtailment periods are for minutes at a time. With that in mind analysis was undertaken to understand what affect not using the FLM data has on the customer curtailment and overall cost.

Under a scenario where FLM data is not used, the customer must accept that they will be curtailed for every network configuration which would potentially increase the fault levels above acceptable fault level ratings.

Expanding on the example shown in the curtailment study in 3.3, Table 4-1 gives a breakdown of what curtailment the customer would have received without input from the FLM.

Mitigating Action	Av. No. of Actions per Year	Average Length of Action (Minutes)	Typical Times When Action May be Required	
800kVA Gas Generator Disconnected	4	3	9.30am	2.30pm to 4.30pm
4.7MVA CHP Disconnected	4			

Table 4-1: Customer Curtailment Without FLM FL Data

Table 4-2 illustrates the customer curtailment with FLM data considered as contained in 3.3 for reference. It can be seen that the customer is likely to receive, on average, 4.32 additional curtailment instructions per year, without the FLM present, of a typical length of three minutes.

Mitigating Action	Av. No. of Actions per Year	Average Length of Action (Minutes)	Typical Times When Action May be Required	
800kVA Gas Generator Disconnected	1.16	3	9.30am	2.30pm to 4.30pm
4.7MVA CHP Disconnected	2.52			

Table 4-2: Customer Curtailment with FLM Data

Using the trial customer as an example the cost implications of either option, with and without an FLM, are:

No FLM - Total cost to customer £25,000 (No FLM contribution); and
FLM Data and reduced interruptions – Total cost to customer £91,000.

These costs show that for a cost saving of £66,000 the customer would potentially experience an extra 4.32 curtailment instructions per year.

This final comparison is particularly important as it gives potential customers a complete picture of the options available. Using this data they can make full assessment of the impact of interruptions on their operation together with associated anticipated cost. This should lead to a natural conclusion on the connection approach to be taken.

From this study it is recommended that Fault Level Soft-Intertrip be defined as either “Fault Level Soft-Intertrip” or “Fault Level Soft-Intertrip with FL Input”. This approach will give the customer greater choice on cost and potential disruption to suit their business needs. It must be considered that this is only appropriate where fault level constraints are present only for maintenance programme conditions.

5 Conclusion

Key learning has been generated from the commercial and engineering elements of the Fault Level Soft-Intertrip scheme trialled as part of the FlexDGrid project. As described above a wide variety of options have been considered when formulating the requirements. Following the successful trial at a customer’s premises and the production of the key policies and associated documents to support the offering and installation of the enhanced Soft-Intertrip schemes these are now available for all 10 FLM sites that have been implemented as part of FlexDGrid.

6 Learning

Table 6-1 summarises the main learning points that have been captured within this report that could be used for future innovation projects.

Item	Learning
Limitations of 'Intellirupter' locations	As the project progressed to Closed-Loop testing it was found that any established processes would benefit from having full site FLM visibility. The final FLM installations were all single FLM installations chosen through detailed site surveys. A single site with multiple FLMs installed would have allowed for a full cost benefit analysis of full visibility versus the monitored modelled approached as utilised on this project. Whilst difficult to accurately anticipate at the project design stage, learning to take from this could be to allow for an increased level of flexibility in at least one site when undertaking multi installs to accommodate any future demands in at least one of the sites.
On-Demand Intellirupter	Similar to above it was found that as the project progressed there was a requirement for an on-demand fault level reading. Whilst there was adequate flexibility in the chosen hardware provider to facilitate any changes the need to undertake on-site commissioning tests after the changes added an additional time and resource requirement. We would recommend undertaking a study at the design stage, for projects similar to this, based on the anticipated potential benefit of over specifying the communications and control signals to cover any future eventualities.
'Do Nothing' Option	Initially the focus of the commercial developments focused on the use of the FLM data in line with the aim of the FlexDGrid project. However on detailed analysis of the outputs it was found that an additional approach to 'Fault Level' management could be taken without the FLM outputs, see section 4.4. The learning taken from this is to ensure, that whilst working towards the project objectives, to be aware of any other potential solutions which may add value and offer up worthwhile customer solutions.

Table 6-1: Learning Points

The information presented in this document demonstrates the successful development of novel commercial frameworks with generation and demand customers. In addition, the document captures the processes that have been followed and the main learning points that have arisen through the implementation of the project.