electricity north west

Bringing energy to your door

Respond

Evaluation of Fault Current Limiting service provision report

31 May 2017

RESPOND

CONTENTS

VERSION HISTORY

Version	Date	Author	Status	Comments
1	31 May 2017	Tracey Kennelly	Complete	

APPROVAL

Name	Role	Approved
Paul Turner	Innovation Delivery Manager	
Steve Cox	Engineering & Technical Director	

GLOSSARY OF TERMS

Abbreviation	Term
AC	Alternating current
CCCM	Common Connection Charging Methodology
CEP	Customer engagement plan
CB	Circuit breaker
CHP	Combined heat and power or cogeneration plant
BAU	Business as usual
DCUSA	Distribution Connection Use of System Agreement
DNO	Distribution network operator
DG	Distributed generation
DPS	Data privacy statement
DUOS	Distribution Use of System charges
ECP	Engaged customer panel
FCL service	Fault Current Limiting service
GB	Great Britain
I&C	Industrial and commercial
LCN Fund	Low Carbon Networks Fund
NTC	National Terms of Connection
Ofgem	Office of Gas and Electricity Markets
Q&A	Question and answer
SME	Small and medium enterprise

FOREWORD

This report is submitted as part of Electricity North West's Respond project, which is funded by Ofgem's low carbon network (LCN) fund second tier mechanism. Electricity North West received formal notification of selection for funding on 24 November 2014. The project will run for 46 months, between January 2015 and October 2018.

The project seeks to demonstrate the viability and effectiveness of a range of mitigation techniques to overcome the fault level challenges faced by distribution network operators (DNOs).

The results of the analysis outlined in this report are derived from a research methodology submitted as part of the Respond customer engagement plan (CEP). The CEP sets out the approach and activities that will be undertaken throughout the Respond project. The project's data privacy statement (DPS) describes how personal data will be managed. These documents are published on the key documents page of the Respond website. These were submitted to Ofgem on 17 June 2015 and confirmation of DPS approval was received on 12 August 2015. The CEP was not subject to approval because the project does not involve engagement with 'relevant' customers.

This report is one of a series of project dissemination documents and serves as an addendum to the Respond interim customer survey report, published on the project website in February 2016. This summarised the lessons learned from a piece of qualitative market research, involving a representative sample of large industrial and commercial (I&C) organisations, to evaluate the market for a commercial solution to manage system fault level and to test the price point at which customers are willing to engage.

This report specifically references the qualitative evidence and commercial learning obtained, from developing the commercial framework to purchase a fault level response, namely the Fault Current Limiting (FCL) service, and the motives and barriers identified by I&C customer, when taking the solution to market.

1 EXECUTIVE SUMMARY

1.1 Background and objectives

As Great Britain (GB) moves to a low carbon future, demand for electricity is expected to rise significantly and this will result in some inevitable increase in fault levels on the distribution network. Respond is an innovative solution to managing 'fault current', which is the instantaneous surge of electrical energy that occurs under fault conditions.

Respond uses an intelligent Fault Level Assessment Tool to calculate potential fault current in near real time, in combination with two new technical solutions and an innovative commercial concept called the FCL service. The commercial technique allows customers operating large alternating current (AC) rotating plant, such as generators and motors to generate revenue from providing the DNO with a fault level response, via a managed agreement.

The FCL service is a form of adaptive protection, which can be deployed at a customer's site. This arrangement will allow the DNO to actively manage fault current, in the event of a network fault, when fault level is high, by remotely constraining the partner companies' equipment; thereby, reducing the flow of current from the plant onto the network.

The project background is fully documented in the Respond submission document, which is published on the project website.

1.2 Customer engagement methodology

The initial phase of customer engagement in Respond involved consultation with an Engaged Customer Panel (ECP) made up of technical and commercial representatives from large organisations in North West England. The ECP was convened to influence the development of a customer survey and supporting communication materials. The survey was designed to establish if I&C customers have an appetite for a commercial technique to address the fault level problem and identify the price point at which they are willing to engage.

A robust customer survey was conducted over the winter of 2015/16 with I&C customers from across GB. The survey also sought to identify up to five demand and/or generation customers that were willing and able to trial the technical and commercial elements of the FCL service.

Post survey customer engagement method

Previous experience has demonstrated the challenges of engaging I&C customers about new commercial concepts and this phase of consultation was no exception. The project team contacted all survey respondents, with sites in the North West that had expressed an interest in the trial, and had consented to their information being shared, for this purpose.

All survey respondents that identified their organisation as being potentially, technically able to provide a fault level response were approached and offered a face to face meeting. Those subsequently confirmed to fulfil the technical criteria, were invited to take part in the active trial phase of the project.

This engagement strategy focussed on explaining the nature of the FCL service trials and acquainting suitable customers with the financial opportunities that might be available to their organisations from participation. This activity generated little interest and the project team consequently explored alternative methods of increasing awareness to facilitate a route to purchase a requisite number of managed agreements, to test the technical and commercial elements of the FCL service.

This included further exploration of Electricity North West's databases of organisations with direct connections to the HV and EHV distribution network; those operating distributed generation (DG) and a suitability assessment of new connection and G59 applications made to its Energy Solutions business.

1.3 Identification of the target market

A key premise of Respond is that the method enables a market for the provision of a commercially viable FCL service. Survey analysis confirmed that, theoretically, a market does exist for the method, proving a key project hypothesis. Nevertheless, appetite is limited and restricted to certain I&C customer sectors. This finding gives support to the challenges encountered by the delivery team when introducing the service to the marketplace and the creativity necessary to both identify and engage customers, with a view to purchasing FCL services for a trial period.

1.4 The challenge of recruiting trial participants

Previous experience has demonstrated the challenges of engaging I&C customers about new commercial concepts, most notably in Electricity North West's LCN funded project, Capacity to Customers (C_2C). Customer consultation in Respond underpins the difficulties of engaging decision makers in large organisations.

The process of recruiting a sufficiently robust number of survey participants, early in the project, was particularly challenging; however, attempts to re-engage survey respondents was more difficult still, despite adopting a carefully considered communications strategy.

The robust engagement approach, designed in conjunction with a market research partner, very experienced in this field, generated little interest in the FCL service generally. The strategy was also not as successful in engaging the number of potential trial participants as had been hoped or envisaged at the outset of the project. Consequently, the project team was unable to transition any survey participant through to active trial participation.

The method has not been embraced by new connection customers or consultants acting on their behalf and as such, it has also not been possible to purchase an FCL service from this sector. However, through continued collaboration with trusted partners and a sustained strategy of speculative communications, to highlight and broaden the reach of the project, the delivery team has fulfilled a project commitment to secure the trial of adaptive protection at two sites in North West England.

1.5 DNO considerations - commercial, security and resilience

Both the DNO and its customers are faced with a number of technical and commercial issues that provide varying degrees of concern about the suitability and applicability of deploying adaptive protection at a customer's site. These must each be considered individually and assessed against alternative fault level mitigation techniques that might be more effective and deployed more quickly and securely at a secure DNO site. This evaluation should consider the overall installation, lifetime or fixed term costs of other methods and the fault level headroom created by each.

An overview of the commercial and technical issues for the DNO are summarised below and documented more thoroughly in Section 5. Issues and challenges that are more pertinent to customers are referenced in Section 6 of this report.

Commercial and regulatory considerations

- Increase in system fault level can be due to the connection of new load or because of a general increase in demand and/or generation connected to the network. For a general increase in system fault level, reinforcement is fully funded by the DNO as part of their capital programme. Network reinforcement required by an increase in fault level due to a new connection requires a financial contribution from the customer, in accordance with the Common Connections Charging (CCCM) reinforcement apportionment rule, with the balance being funded by the DNO as connections driven reinforcement. This raises a number of issues when considering the purchase of fault mitigation services from both existing and new connections customers.
- Provision of fault mitigation services by a third party will incur ongoing costs. These must be considered against capital expenditure on traditional reinforcement, involving primary switchgear replacement. Any decision to purchase a managed service should be assessed against the short, medium and long term benefits to both the DNO, and all GB customers, who partially or fully fund fault level reinforcement costs through the Distribution Use of System (DUoS) charges.
  This assessment must consider the cost of purchasing the service against saving from deferring asset replacement and the fault level headroom created via a managed agreement.
- Adaptive protection involving work at customer's premises will generally cost more than an installation at a DNO substation as a result of longer planning and installation times and the requirement for remote communications. It would also necessitate customer outage downtime, likely to result in loss of export revenue.
- The financial viability and appropriateness of this commercial solution to fault level should be assessed against other technical solutions being considered in Respond and new technical and commercial techniques currently being investigated by other GB DNOs.
- The loss of revenue by generators due to being disconnected during a TRIAD payment period has an impact on the level of payment required to purchase a FCL service.

Technical considerations

- The service will always be required when system fault level is above the switchgear rating.
- All techniques being investigated under Respond are subject to a safety case, cost benefit analysis and a carbon Impact assessment before they can be adopted into business as usual (BAU) as a fault level mitigation solution. These investigations will be based on trial evidence and inform a buy order of fault level mitigation solutions.
- Contribution to fault level at the restricting asset (usually a circuit breaker at the primary substation) is dependent both upon:
    - The contribution from the customer's motor/generator (subject to the type and rating of the equipment).
    - The electrical impedance between the motor/generator and the restricting asset.
- A customer provided FCL service will always require adaptive protection technologies at both the controlling circuit breaker (CB) (that has the restriction), the CB controlling the customer's motor/generator (that is to be disconnected in the event of a fault) plus a communication link.
- A mechanism is required to ensure that customer cannot disable the relay/CB to prevent operation when it is required to reduce fault level. However, for the purpose of the trial, which is limited to networks where there are no fault level issues, we will ensure that the customer retains the ability to locally isolation their CB.
- The application of an adaptive protection system at a DNO's primary substation will generally provide a greater reduction in fault level compared to the headroom provided by disconnecting a customer's motor/generator.
- The increased operating frequency of a customer's CB may require an enhanced maintenance regime and associated additional costs.

1.6 Customer drivers and barriers identified

Direct customer consultation has identified that financial benefits are the primary driver in encouraging suitable organisations to consider the provision of a fault level response; however, assessment of reward versus risk is one of the primary barriers in transitioning these organisations from an indication of interest to meaningful commercial discussions.

The key areas of concern are nervousness about risk and resilience to equipment, processes and overall business operations; security of supply; relinquishing control of protection equipment; ambiguity around the number and frequency of future events; potential down time and the wider impact that this could have on service level agreements with their own end-customers. Other concerns include exposure to the risk of significant penalty payments associated with the TRIAD charging mechanism and loss of revenue from other capacity and balancing schemes.

Financial arrangements to offset these barriers and challenges have proven to be a significant impediment to moving discussions forward to formal contractual negotiations for the purpose of securing the purchase of an FCL service.

These issues are fully documented in Section 6 of this report and the findings from this phase of consultation largely corroborate learning from the customer survey and ECP phase of research.

Research has identified that this market sector is not only extremely risk averse but their ability to make decisions about possible commercial opportunities, are influenced by the earning and saving potential provided by other schemes in the capacity and balancing market. Furthermore, complex operating arrangements can constrain a customer's ability to agree to new commercially driven services, particularly where critical plant is owned, operated and subject to warranty conditions dictated by a third party provider.

1.7 Meeting success criteria - purchase of a managed service

At the date of this report, Electricity North West has agreed terms to test the technical and commercial elements of the FCL service at two sites operated by the Respond project partner, United Utilities. These consist of one demand and one generation site.

The project team is also near to agreeing terms to purchase a managed service from a commercial grower and is currently finalising technical arrangements concerning the installation. This customer is a generator operator who is keen to participate in the trial for a limited period, subject to a number of contractual caveats.

Early negotiations are also taking place with a health care provider, currently in the process of installing new generation at an existing HV connected site, within the project timescales.

There are no fault level issues on any of the Electricity North West networks where Respond trials are taking place. FCL service trials will also only be conducted on networks after the fault level has been assessed and confirmed to be well within acceptable limits, to ensure that if the technology fails, there is no risk of any equipment exceeding its rating. Therefore, for the purpose of the trial, protection settings on equipment at these sites will be lowered to facilitate the enablement/operation of the controlling technologies. In the absence of network faults during the trial period, which cause the CB to trip, the project team will artificially simulate a fault level response.

For the purpose of the trial, this approach will allow Electricity North West to manage both the time and number of tests conducted, in order to evaluate the operation of adaptive protection deployed at a customer's site. This approach appears to be more appealing to customers and may be influential in securing the optimum number of trial participants to test enabling technologies.

The delivery team will continue to collaborate with internal and external stakeholders to identify and engage with other potential trial participants.

1.8 Conclusions

A number of important regulatory, safety, technical and commercial considerations have been identified during this phase of research, which introduce questions about the viability of adopting the FCL service, into BAU as a practicable, long term fault mitigation solution. These are a particular concern when purchasing the response from existing customers and as such, application of the method as a new form of constrained connection agreement is more appropriate for the DNO. Nevertheless, there remain a number of challenges common to both new and existing customers that must be addressed and overcome before it is possible to validate the method.

Overall viability of the solution must be assessed against the whole lifetime costs of the traditional reinforcement solution to fault level and the innovative techniques investigated in Respond, which may be deployed more efficiently, at less cost, provide greater headroom and afford the DNO with greater network security.

Nonetheless, application of an FCL service, in the form of an alternative constrained connection agreement, for new customers, could theoretically provide a short term solution to a fault level problem during the planning and commissioning stages of alternative methods, it also negates the requirement for ongoing payments by the DNO.

1.9 Next steps

The final piece of customer research in Respond will be undertaken with organisations that actively participate in the FCL service trial, via a fixed term managed agreement. This study will allow Electricity North West to evaluate the experience of these customers. The findings will be documented in a final customer report, due to be published in May 2018.

Contractual differences have delayed installation of enabling technologies at partner sites and terms have yet to be agreed to deploy adaptive protection at any customer premise. As such, the final phase of customer research has yet to commence and therefore, it is not currently possible to evaluate industry confidence in the proposed method or the enabling technologies that facilitate the technique.

2 BACKGROUND AND OBJECTIVES

2.1 Business objectives

As GB moves towards a low carbon future, demand for electricity is expected to increase significantly with an inevitable increase in fault levels on the distribution network. Respond is an innovative solution to managing 'fault current', the instantaneous surge of electrical energy which occurs under fault conditions. Fault level is the potential maximum amount of fault current that will flow when a fault occurs.

An increase in system fault level can arise due to the connection of new load or because of a general increase in load and generation already connected to the network. If either of these scenarios were to cause the potential maximum fault current to rise above the network fault level rating, then the DNO's protective circuit breakers may be unable to interrupt the flow of fault current, which would result in disruptive failure.

2.2 Traditional method of resolving the problem

DNOs are required to maintain safe operation of the electricity distribution network at all times and the traditional solution to an increase in fault level above the rating of existing switchgear is to replace it with switchgear having a higher fault level rating. Therefore, when system fault level increases, even if the switchgear rating is only likely to be exceeded very infrequently, it would necessitate asset replacement. Installing expensive, higher specification switchgear in these circumstances means that the extra fault level capacity installed is effectively unused for the majority of the time.

Traditional reinforcement usually involves changing high voltage (HV) or extra high voltage (EHV) switchgear at the primary substation. In RIIO-ED1, the cost of replacement for a single substation is around £0.5m for HV and starts at £1.2m for EHV.

For a general increase in system fault level the cost of reinforcement is fully funded by the DNO as part of its capital programme. However, an increase in fault level arising from a new connection requires a contribution from the customer in accordance with the Connections Charging Reinforcement Apportionment rule', as specified in DCUSA section 22 paragraph 1.26 and **Electricity North West's Common Connection Charging Methodology Statement** **(**Section 5) with balance being funded by the DNO as a connections driven reinforcement. This is discussed further in Section 5.1.

2.3 The Respond solution

Respond seeks to demonstrate that a network's fault level can be estimated in near real time, and in responding to that estimation, a series of innovative technical and commercial techniques can be initiated to reduce fault level, without the need for expensive and time-consuming asset replacement. As this approach could maximise the use of existing assets and minimise the need for capital investment, Respond has the potential to realise significant cost savings to customers and improve the connection of generation to the network. There are four key elements to Respond:

Fault Level Assessment Tool

Respond will deliver a Fault Level Assessment Tool which calculates potential fault current in near real time. This platform enables one of three innovative fault level mitigation techniques

to be adaptively controlled, to manage fault current safely. This intelligent software has been deployed alongside Electricity North West's network management system (NMS)and continuously analyses the data from it, to calculate the network's fault level at any given time. When the fault level is increasing beyond a set threshold, it initiates one of following three mitigation techniques:

- **Adaptive Protection:** This technique re-sequences the operation of DNO owned and operated protective circuit breakers (CB) and the technology facilitating this response is retro-fitted into existing substation equipment
- **Is-limiters:** These devices are installed to split the HV busbar or disconnect a primary transformer. They are widely utilised internationally to limit fault current, but are not currently used on GB DNO networks due to compliance issues with GB regulations. Two devices have been installed as part of Respond. Is-sensing installations have also been deployed at a further five sites for monitoring purposes only.
- **Fault Current Limiting (FCL) service:** This commercial solution involves the installation of adaptive protection on 'customer owned' large alternating current (AC) rotating plant, such as motors or generators. The technique operates in a similar manner to adaptive protection at a substation; however re-sequencing of protection extends to the customers site. This 'customer provided' response offers the DNO fault level mitigation when fault level is high and a network fault occurs.
  In these circumstances, remote activation of enabling technology, controlled by the DNO, instantaneously disconnects the customer's equipment via its controlling CB. This immediately removes its contribution to the flow of fault current; thereby, reducing overall system fault level, allowing the DNO to safely clear the fault on its network. The FCL service has the potential to allow existing and new connection customers, operating large plant, to benefit financially from selling a fault level response to the network operator.

This report specifically documents the key findings from a strategic phase of qualitative customer engagement, which was designed to identify suitable customers, operating suitable equipment that might be prepared to trial the commercial and technical elements of the FCL service. It was envisaged that this would culminate in the purchase an FCL service from at least one demand customer and one generation customer operating in North West England.

This document considers the most appropriate route to market, the commercial challenges associated with the FCL service method and the optimal pricing structure to purchase this type of managed agreement.

3 CUSTOMER ENGAGEMENT METHODOLOGY

A key hypothesis of Respond is that the method enables a market for the provision of an FCL service. The initial phases of customer engagement led to a GB wide customer survey, conducted in the latter part of 2015, to assess the commercial appetite and optimal price point for the method.

Provisional findings from interim analysis of the survey indicate that certain I&C sectors find the technique appealing, suggesting that a market does exist, primarily among non-manufacturing customers. These findings are summarised in Appendix 11.1 and documented more thoroughly in the interim customer survey report, published on the **Respond website.**

A subsequent phase of qualitative market research was undertaken in April 2016 with a reconvened ECP of I&C customers, charged with evaluating materials and a strategy to introduce the FCL service to potential trial participants in the commercial marketplace. The lessons learned from this phase of engagement are documented in the second ECP report, which is published on the project website.

Post survey customer engagement method and adaptations

From the project's outset, it was recognised that it would be challenging to engage large I&C representatives to participate initially in customer research and incrementally more complicated to encourage them to consider trial participation. Adaptations to the survey methodology, designed to maximise response rates and thus exploit the learning opportunities are outlined in Appendix 11.1. The approach to overcoming the challenges associated with actively recruiting I&C trial participants is covered in Section 4.

3.1 Identification of the target market

Representative from a total of 103 organisations participated in the customer survey. Of these, a total of 47 operated sites located in Electricity North West's operating region; expressed an interest in the FCL service and consented to the market research partner sharing their information with the project team.

Analysis of these individual survey responses identified that:

- Only 11 of the 47 organisations were prepared to realistically consider taking part in the trials, on the basis that they operated suitable equipment that could be constrained, without significant impact. Of these, five had at least one other commercial arrangement in place.
- Despite an extensive 'pre-survey' screening process, seven of these 47 respondents were found to operate equipment which did not strictly meet the FCL service criteria. Nevertheless, these customers were offered a follow up meeting on the basis that they could potentially earn a financial incentive from providing limited participation in the trial, by allowing the project team to test enabling technologies.
- In addition to the 11 organisations referred to above, a further six respondents confirmed they operated potentially suitable equipment at sites in the North West and were interested in the trials but failed to specify if a constraint might have an impact on their operations. These customers were furnished with more information about the trial and offered a face-to-face meeting to discuss the technique in further details.

Respondents that expressed reservations about the suitability of the technique for their particular organisation, citing particular barriers and risks, were encouraged to meet with the project team to discuss their unique concerns. This approach was designed to maximise project leaning, whilst ensuring that technique was fully explained to individual customers.

This one-to one engagement strategy was designed to offer complete transparency, and provide individual customers with all the information they might require to assess how the FCL service might impact their particular organisation and importantly, ensure that no potential trial participant was discounted from the process on the basis of a lack of understanding.

3.2 Purchase of a fault level response from existing customers

The project team sought all opportunities to open discussions about active trial participation with the 11 organisations, confirmed by their survey responses to: be interested, likely to fulfil the technical criteria and critically, have the ability to provide a fault level response, without any significant impact on their equipment or operations.

This process involved consulting decision makers from each organisation directly. This strategy resulted in expressions of interest from four organisations, which resulted in face-to-face meetings.

The delivery team introduced the trial, its objectives and potential benefits to both commercial and technical decision makers in the organisations, using the communication materials that had been endorsed by an ECP (details of which are provided in the second ECP report, published on the project website). This approach was well received and effective

in communicating the fault level problem which was the aim of the project generally and the FCL service specifically.

All customers responded positively to the technical concept and understood the proposed pricing mechanism together with the factors influencing the benefits that might be available to their respective organisations. This validates the overall strategy as having provided a suitable introductory platform to take the FCL service to market.

Direct engagement with the four organisations, identified that three were unable or unsuitable to enter into a managed agreement to trial the FCL service for at least one of the reasons outlined below:

- Site/equipment is unsuitable as it is covered by multi-occupancy and maintenance agreements
- Equipment identified as not operating in parallel with the distribution network
- New plant will not be installed and commissioned within the project timescales
- Plant is temporarily out of commission and unlikely to be re-commissioned within project timescales.
- Site owner is in existing negotiation or contract with developer/manufacturer/consultant concerning the management of the plant and the benefits of other commercial services available including TRIAD, STOR and frequency response.
- Other commercial agreements are already in place or pending with aggregators

Customers meeting the technical criteria were invited to take part in the active trial phase of the project. Most were theoretically interested and motivated by the financial incentive, but were constrained for the reasons outlined above. They also vacillated on particular benefits to their respective organisations.

3.3 Re-engaging existing customers to enhance commercial learning

It has proven particularly difficult to re-engage survey participants, who responded positively to the survey and expressed an interest in taking part in the trial. For those who were prepared to meet the project team and to discuss FCL service provision in greater detail, it was extremely challenging to secure subsequent follow up meetings and engage in more meaningful dialogue with decision makers. A number of stated and implied barriers have been influential in customers' decisions to decline the offer of further discussion about potential trial participation and these are discussed in Section 6.

All directly engaged customers were encouraged to provide more detailed feedback about the technique and perceived applicability/suitability for their respective organisations. Despite repeated attempts to re-engage these customers, the project team was unable to elicit further information to supplement commercial learning or determine the grounds for the organisations' decision not consider trialling the service. The approach to overcoming the challenges of engaging these customers is outlined in Section 4.

3.4 Purchase of a fault level response from new customers

Throughout the project, the delivery team has collaborated with colleagues from Electricity North West's Energy Solutions business to highlight the Respond trial to new customers, particularly those installing new CHP/cogeneration plants. None were prepared to complete a survey and as such, new connection customers were directly approached to assess their suitability and interest.

The challenges of engaging new customers together with the lack of appetite in this sector and the particular barriers/perceived risks that have been identified are discussed in Section 4.2.

3.5 Unsuitable customers – too small or not connected in parallel

Organisations that expressed an interest in the trial but operate only standby generation that provides a back up source of power, isolated from the distribution network, during a distribution system outage are unable to provide an FCL service. As such, these customers were discounted from the engagement process, as were generators not operating in parallel with the network and therefore, not contributing to fault level. Operators of equipment deemed too small to meet the project brief and not sufficiently or consistently impacting overall system fault level were also discounted.

4 THE CHALLENGE OF RECRUITING TRIAL PARTICIPANTS

The extent of the challenge involved in recruiting trial participants was considerably underestimated because the project team did not anticipate the degree to which this market sector was resistant to the technique generally, the value placed on the continuous operation and control of critical assets and the financial expectations of providing an elective commercial service to the DNO.

The barriers that have prevented customers from transitioning from an expression of interest in the survey, to active participation in the trial are documented in Section 6 and these findings corroborate learning from the ECP feedback and analysis of the customer survey.

The following measures were adopted to promote the trial and encourage customers to consider participation:

4.1 Continued engagement with existing customers to enhance commercial learning

All directly engaged customers were encouraged to provide more detailed feedback about the technique and perceived applicability/suitability for their respective organisations. In their response, they were asked to consider obstacles and risks and identify the key drivers in the appetite to pursue. These organisations were also asked to conduct an evaluation of viability and cost benefit, to determine the minimum price point at which they might theoretically be prepared to consider providing Electricity North West with a fault level response. Customers were provided with a copy of the draft framework agreement and invited to comment on the template overall and specifically, any terms and clauses that their organisation found unacceptable.

Despite repeated attempts to re-engage these customers, the project team was unable to elicit further information to supplement commercial learning and fundamentally, to determine the particular grounds for the organisations' decision not to pursue the potential benefits available from a managed agreement to trial the FCL service.

Lack of interest and perceived barriers have prevented the project team from gaining traction with any of the organisations that participated in the Respond customer survey and as such, it has not been possible to transition these I&C customers through to managed agreements for the provision of an FCL service.

After several approaches to representatives of these companies, via direct mail and telephone, attempts to re-engage were terminated, so as to avoid negatively affecting the credibility of the project and critically, prevent any adverse reputational impact to Electricity North West and its project partners.

4.2 Engaging new connection customers

The project team have worked alongside Energy Solutions colleagues to identify new connection customers, meeting the project criteria and highlight the commercial opportunity afforded from taking part in the trial.

A significant proportion of demand and generation connection applications, that met the criteria, were discounted because they necessitated significant and time consuming reinforcement works that will not be completed within project timescales.

Other customers, with connection installations near completion, declined on the basis of commercial negotiations with third parties (discussed in Section 6.9).

Reluctance to engage in an unproven technique is likely to be amplified in organisations that intend operating new and expensive equipment. As such, it is reasonable to speculate that new customers are probably more risk averse than some existing customers, and unprepared to expose critical new plant to unnecessary and unquantifiable vulnerability.

Despite these issues, the potential exists to apply the method as a new form of constrained connection agreement, for new customers including those adding new generation in the future. This could provide customers with cost effective and quicker connections compared to the traditional solution if the benefits for the organisation offset any barriers. This application of the technique is discussed in Section 7.3.

A number of new generation plants were identified as providing the potential to offer an FCL service within the trial period. However, interest amongst these organisations (and consultants acting on their behalf) has tended to be notional in nature. Those willing to engage were all existing customers in the process of connecting new generation plants at established sites that were already connected to the HV network.

On site meetings have taken place with three of these new customers and as a result of this consultation process, one organisation is keen to participate in the trial. However, this customer's generation plant is unlikely to be commissioned in sufficient time to provide a robust trial of the method. Nonetheless, the plant affords the technical workstream the opportunity of testing enabling technologies for a limited trial period to supplement the learning expected from existing customers taking part in the trial (United Utilities and a commercial grower).

At the date of this report, contractual negotiations are at an early stage and the purchase of a managed service from this organisation is subject to approval from their management/legal team and the mutual agreement of a suitable, and as yet undetermined, payment.

At this stage of the project, in the absence of direct feedback from new customers and their representatives, it is not possible to definitively determine the reasons for lack of interest in this sector. However, the main barriers are likely to be akin to those identified by existing I&C organisations, operating both within and beyond Electricity North West's distribution region, outlined in Section 6.

4.3 Collaboration with partner organisations

Electricity North West's previous experience of innovation projects involving I&C customers, most notably in C_2C, provided insight into the difficulties of initially engaging commercial and technical decision makers in large organisations, the challenge of building relationships and ultimately, agreeing terms for trial participation.

This learning identified the value of collaborating with trusted partner organisations that have access to, and well established relationships with, third parties. These project partners can help with introductions and identify the right person to talk to in commercial organisations. As such, the Association for Decentralised Energy (formerly the Combined Heat and Power Association) and Ener-G, a cogeneration provider, were appointed to help overcome barriers and support customer engagement activities throughout the project.

The project partners initially aided the project team in the recruitment of suitable survey participants' from across GB by promoting the FCL service through a range of internal and external channels, which included newsletters and other publications; social media platforms

and direct face-to-face or telephone contact with members/customers and other industry associates.

The partners subsequently supported the project team by helping to actively recruit trial participants. Because of the limited interest generated from the survey population, they identified and consulted decision makers from selected organisations operating in the North West, to promote awareness and make preliminary introductions. During this consultation process the partners offered to attend and support customers during initial meetings. However, despite partner support, it has proven extremely challenging to engage large I&C demand and generation customers at every stage of this project.

4.4 Continuing customer engagement methodology

The project team is now close to securing a managed agreement with one existing customer and is involved in promising negotiations with a new connection customer. This has only been possible because of a sustained strategy of speculative communication, to highlight and broaden the reach of the project, in collaboration with internal stakeholders and trusted partners.

The technical workstream has now finalised arrangements to commence trials of adaptive protection at two sites owned and operated by project partner, United Utilities and details of the pending agreements are discussed in Section 7.2.

The project team is continuing to work closely with project partners ADE and Ener-G to publicise the project and attract more potential trial participants amongst their respective customers, associate members and industry contacts. However, at this stage of the project, it is unlikely that the necessary commercial and technical arrangements, to secure a managed agreement with a newly engaged customer, will be finalised in sufficient time to facilitate the robust trial of adaptive protection, at a price and terms agreeable to both parties.

5 DNO CONSIDERATIONS – COMMERCIAL, SECURITY AND RESILIENCE

The FCL service trial has been designed to demonstrate how commercial mechanisms can incentivise large customers to alter the way in which they connect to, and use the network. Section 6 outlines the market sectors where appetite for this solution is likely to exist and the key customer drivers and barriers for this type of commercial solution to limit fault level.

However, this research has highlighted a number of important factors for the DNO to consider it its viability assessment of the technique. These can be broadly categorised as commercial or regulatory and technical considerations, which are briefly summarised as follows:

- **Commercial & regulatory**
  - Connections Charging Reinforcement apportionment rule
  - Ongoing costs
  - Incentives
  - Cost benefit
  - Applicability and payment where headroom created by the solution is restricted

- **Technical**
  - Technologies, installation and operational costs
  - Continuous availability of service
  - Frequency of a fault level response
  - Multiple providers and prioritisation of response
  - Fault Level contribution of customer equipment
  - Security and resilience

- Additional maintenance
- Safety case and post trial analysis

These issues are discussed in further detail below:

5.1 Commercial & regulatory

Connections charging reinforcement apportionment rule

An increase in system fault level can be due to the connection of new load or because of a general increase in demand and/or generation connected to the network. Electricity Distribution Licence Conditions 13 and 14 requires DNOs to formulate, publish and apply a Common Connection Charging Methodology (CCCM) for calculating the costs to new or existing customers wishing to connect to their distribution network or increase their power requirements from an existing connection. The CCCM places an obligation on the DNO to provide the conectee with the least cost solution; however, the overall cost to all customers must be considered.

The principle underpinning the methodology is that the connectee pays for the cost of the new connection assets and a proportion of the cost of reinforcement to accommodate the new connection up to one voltage level above the voltage of connection. All customers, through DUoS charges, fund the reinforcement costs not funded by the connectee. All customers fund fault level reinforcement associated with general growth in load and micro-generation.

For a general increase in system fault level, reinforcement is fully funded by the DNO as part of their capital programme. An increase in fault level due to a new connection requires a contribution from the customer, in accordance with the CCCM reinforcement apportionment rule (as defined by the Fault Level Cost Apportionment Factor calculation), with the balance being funded by the DNO as connections driven reinforcement. This raises a number of issues when considering the purchase of fault mitigation services from both existing and new connections customers.

The current CCCM does not facilitate the cost apportionment of the alternative fault current mitigation techniques considered by Respond. The impact on the CCCM will be investigated as part of the project and a Distribution Connection Use of System Agreement (DCUSA) change proposal for amending the application approach to the Fault Level Cost Apportionment Factor in the CCCM will be submitted in August 2018.

CCCM - new customers

- The Electricity Connection Charging Regulations (ECCR) make provision to recover the costs of connections driven network extensions by requiring a future connectee to make a contribution to the initial costs of any shared asset. ECCR applies only to the cost of providing a new connection, not to the reinforcement, as the customer only pays for the proportion of the network reinforcement that they use. However, it is important to note that where it is unlikely that the additional capacity is required for other customers within five years, then the connectee should pay the whole of the reinforcement cost and ECCR would then apply if the asset was subsequently to be used by another customer.
- The cost of the provision of the service by a new connections customer will be reflected by a lower reinforcement contribution charge and will be governed by specific conditions in the customer's Connections contract.
- Connections charging policy does not currently have a provision for collecting ongoing annual charges from new customers.

CCCM - existing customers

- The provision of an FCL service from an existing customer will require an ongoing payment regime, which could be monthly or annually, may extend for a number of years and will involve additional administrative costs
- There is a need to consider the duration that an FCL service is required, particularly if passing a proportion or all of the costs through to a new connections customer, as this may require regular payments and corresponding pass through charges over many years.
- New customers pay only a proportion of the reinforcement costs; therefore logically, this apportionment would also apply to the cost of making payments to existing customers for the provision of an FCL service.
- The contract with an existing customer to provide a FCL service will have a termination or break clause which could mean that the FCL service could be withdrawn, prior to alternative fault current limiting arrangements being put in place. As such, a mechanism must be applied to 'future proof' the method to provide security to the DNO, discussed further in Section 5.2.

Technologies, installation and operational costs

One hypothesis of Respond is that adaptive protection equipment can be installed on a customer's electrical machine to enable the FCL service and, in common with other retrofit mitigation techniques; this can provide cost savings, to all DNO customers, by extending the life of the existing assets from the deferral of network reinforcement, involving the replacement of primary switchgear.

Assuming that the traditional reinforcement cost is incurred at a point in the future, it will be possible to calculate the minimum deferral period (ie the financial breakeven point) for entering into a managed agreement, based on capital and operational costs, which include ongoing payments to the customer/s providing the service over a fixed term (Section 5.1).

Traditional reinforcement costs, associated with the change of primary substation switchgear, are ~£442k and ~£1220k for EHV switchgear. These costs are estimated with a number of key assumptions, as specified in Section 3 of the Respond submission document, which is available to view on the Respond website.

An FCL service, provided by either a new or existing customer, will require adaptive protection technologies at both the controlling CB on the circuit at the primary substation(which has the restriction), the CB controlling the customer's motor/generator (that is to be disconnected in the event of a fault) along with remote communications functionality.

As such, adaptive protection, involving work at a customer's premises, will also be more expensive than at a substation, as it will require the installation of a remote terminal unit to provide a communications link. This figure is not factored into the above implementation costs and will vary from site to site according to the work required at individual sites; however best estimates to fit an RTU range from £7k to £10k.

The private electrical installations of customers together with the equipment connected to their installations and their distinctive functions/processes are unique to individual organisations and specific sites. Whilst all HV connected customers are likely to have multiple CBs protecting their installation and equipment; the number, type and configurations of CB protection will vary significantly. As such, the technical arrangements to facilitate adaptive protection on a customers' equipment and the associated communications, will be bespoke in each instance.

The estimated cost of installing adaptive protection at on a customer's equipment is discussed in Section 5.1. Installation of the interface technologies to a HV connected customers supply will be managed by a suitably authorised project engineer. However, actual costs are expected vary from site to site. Whilst the skills required to conduct this work exist within the DNO workforce and those of existing service providers; additional time and resourcing costs may be incurred because of the bespoke nature of work at individual sites.

Adaptive protection on electrical machines at a customer's premises and calculation of the protection settings is likely to take longer than on distribution switchgear, as more interface arrangements must be ratified. These additional planning and installation costs must also be considered. Furthermore, the installation of adaptive protection on a customer's network may not provide the DNO with the level of security or access to equipment available if it was installed at one of its own sites and consequently, extra security arrangements might be required, which would have a financial impact.

If the FCL service is rolled out as BAU, the cost of installing adaptive protection at a customer's site would be included in the overall reinforcement. The trial will validate capital and operational costs and the breakeven point during the cost benefit analysis

Variation in installation and commissioning costs, along with other issues identified during this phase of the trial will be documented in the final customer report, due to be published in May 2018.

Ongoing costs

Operational costs for the various methods being trialled in Respond are documented in figure 3.2 of the project submission document and these vary significantly. The key determinant for whether the retrofit techniques are applied is the length of time that the reinforcement can be deferred.

However, provision of fault mitigation services by a third party will cause the DNO to incur ongoing operational costs, specifically in the case of existing customers,. These will take the form of either availability and/or utilisation payments. This not only places a long term financial commitment on the DNO but requires them to adopt systems and processes to administer the requisite payments.

These must be considered against capital expenditure on traditional reinforcement, involving primary switchgear replacement. Any decision to purchase a managed service should be assessed against the short, medium and long term benefits to the DNO and all GB customers, who partially or fully fund fault level reinforcement costs through DUoS charges. This assessment will consider the cost of purchasing the service against saving from deferring asset replacement and the fault level headroom created via a managed agreement. The following issues need to also be considered:

- Adaptive protection involving work at customer's premises will always cost more than an installation at a substation as a result of longer planning and installation times and the requirement for remote communications.
- The financial viability and appropriateness of the commercial solution to fault level should also be assessed against other technical solutions being considered in Respond and new technical and commercial techniques under investigation by other GB DNOs.
- The loss of revenue by generators due to being disconnected during a TRIAD payment period has an impact on the level of payment required to purchase a FCL service. These commercial considerations are considered further in Section 6.9.

Incentive (availability/utilisation payments)

The proposed customer payment is calculated based on the cost savings associated with the avoidance of upgrading the network to remedy a potential fault level issue. The offering is calculated on £/kA per event or £/kA per contract, as was proposed in the original project submission. A Respond pricing calculator is published on the project website and the calculation is made on the basis of two elements namely the contribution to system fault level by the customer's equipment and the price per MVA of contribution, which is based upon the deferred cost of reinforcement.

The effect of impedance (discussed in Section 5.2) can significantly reduce a customers' equipment's contribution to fault level and this must be considered in the payment calculation.

The cost of 1MVA of fault level contribution is based on the cost of traditional reinforcement associated with changing the HV switchgear in a primary substation (£442,208) and dividing this value by the rated fault level (250MVA) to provide a rate of £1,769 per MVA of contribution to fault level reduction. This is a cost of providing the service until the asset is due for normal replacement. Therefore, it could require the customer to provide the service for many years. For example over a 20 years period, the customer would receive £88.45 per MVA per year. The cost benefit of a customer provided service involving ongoing payments is discussed further in Section 5.1.

This calculation provides the most appropriate mechanism for the DNO to determine a reasonable offering, based on £/kA per event or £/kA per contract. Indicative incentives, based on this pricing mechanism were introduced to potential trial participants to establish acceptability.

The project team also assessed the suggestive pricing structure against an alternative calculation methodology, similar to that used to calculate the base price point in C_2C (details of which are provided in Section 3.3 of the Interim Customer Survey Report, published on the Respond website).

This method provided a £/kA value for a ten-minute constraint per MW of demand or generation capacity, on the basis of a contribution to fault current. Whist appropriate for C2C, this method is less appropriate to Respond. Nevertheless, the exercise provided a balanced approach to estimating what a DNO might be prepared to pay customers for commercial services and both methods provided figures that were comparable.

On this basis, the second method, whilst less suitable, was easier to incorporate into a choice based experiment, in the customer survey. This was used to help respondents assess the appropriateness of the proposed price point and encourage them to contemplate the level of payment they would be prepared to accept for providing a fault level response.

As discussed in Section 5.1 any decision to purchase a managed service should be assessed against the short, medium and long term benefits to the DNO and all GB customers, who partially or fully fund fault level reinforcement costs through the DUoS charges. This assessment will consider the cost of purchasing the service from a third party against saving from deferral of asset replacement.

Allocation of an appropriate pricing model also presents the DNO with a challenge when considering the fault level headroom created by a managed agreement. For example, there may be a requirement for capacity release of 2MVA to safeguard the DNOs protection equipment at a substation. However, the constraint of a customer's equipment, via a managed agreement, could generate 5MVA of headroom. In these circumstances, what level of capacity does the DNO pay for?

When considering application of adaptive protection at a substation, the DNO would obviously look to create the greatest possible headroom from its capital investment in the enabling technology. However, an ongoing customer payment calculated on a £/kA will present the DNO with disparity between actual need and the payment it might be expected to pay for the service.

Cost benefit

Application of an adaptive protection system at a DNO's primary substation will generally provide a greater reduction in fault level compared to the headroom provided by disconnecting a customer's motor/generator and will avoid the requirement to pay for a FCL service from a third party.

The capital costs for implementation of adaptive protection techniques at primary substation level is ~£18k and ~£31k at EHV. Capital expenditure for the $I_s$limiter solution is ~£324k at HV and ~£531k at EHV. Adaptive protection and $I_s$limiter costs incorporate those associated with the Fault Level Assessment Tool. However, actual expenditure on these fault level mitigation techniques is subject to any variances that become apparent during the course of the trials, which will be reported at closedown.

The proposed incentive mechanism and the basis of its calculation are outlined in Section 5.1. This delivers a proposed payment of £1,769 for each MVA of fault level headroom released by a customer, based on them providing the service until the asset is due for normal replacement. This will differ on each network because of the age of the asset and this will consequently affect the overall payment. Therefore, if the fault level response is require for 20 years, the customer would receive £88.45 per MVA per year. A customer providing 25MVA of fault level headroom would receive around £44k, which if paid annually would overtake the cost of the traditional reinforcement solution after 10 years.

As such, cost benefit analysis will determine the financial viability and appropriateness of a commercial solution to fault level against both traditional reinforcement and other technical solutions being considered in Respond to establish the optimum solution in each instance.

Applicability and payment where headroom created by the solution is restricted

Different types of rotating plant and their connection point on the electricity network have varying contributions to system fault level and therefore, a DNO is likely only to be interested in purchasing a fault level response from a customer operating a motor/generator that significantly contributes to system fault level.

Consequently, the commercial and operational benefits for the DNO of investing in adaptive protection at a customer's premise, is only justifiable where equipment contributes significantly to fault level at the HV busbar, ie where headroom created by the technique is not constrained by the effect of impedance. (refer to Section 5.2)

The payment would only be made on the headroom created at the restricted asset ie the controlling CB. As a consequence, the fee available for existing customers, embedded in remote positions on the network, a distance from the primary substation will be less attractive than those available for customers nearer to the substation containing the restricted asset.

5.2 Technical considerations

Continuous availability of the service

The FCL service must be available 24/7 as it will always be required when system fault level is above the switchgear rating. Enabling technology will be permanently connected to a managed customer's CB and could isolate their equipment at any time, as dictated by network conditions. Ambiguity about the expected frequency of a fault level response each year, the inability to provide customers with protected days, times or an opt out clause to restrict the number of occasions that their equipment might be constrained appears to be influential in the lack of interest and is discussed further in Section 6.3.

Frequency of a fault level response

Before signing up a customer to a managed agreement analysis of system fault history will be undertaken to provide an indication of the anticipated number of occasions that adaptive protection might be required, to constrain the customer's equipment each year. This calculation will consider the percentage of time that the Fault Level Assessment Tool will enable the protection, as the service is only required when the fault level is exceeded. The estimate would then be based on an annual average of the cumulative number of phase-to-phase faults on all HV circuits served by the primary substation, when assessed over a five year period.

This calculation is reliant on the accuracy of historical HV fault data. Traditionally there has been no requirement to specifically report the causation of network faults to this level of granularity and therefore, providing a reasonable estimation of the anticipated frequency of a fault level response, based on historic reporting protocol, is challenging. Refinements to reporting processes are required to ensure that phase-to-phase faults are specifically highlighted, for this purpose going forward.

Furthermore, network conditions are not static and continually subject to the vagaries of faults, third party damage and the impact of extreme weather conditions. As such, any projected estimation of the frequency of a fault level response is at best, speculative.

Electricity North West has a robustly designed network and at present, has no fault level issue that might require this type of response. However, the projected increase in embedded generation will create fault level issues on an increasing number of circuits. Therefore, on the basis of this future scenario and studies of historic faults on typical HV networks; the project team estimate that a customer's equipment might be constrained, on average, twice each year.

Nonetheless, all prospective managed customers will be furnished with details of the fault history of the specific circuits out of the primary substation via which their supply is provided. It is proposed that five years worth of fault history data will be provided, in line with the methodology adopted in C_2C. It is however worth noting that the performance of the distribution network is under constant review and circuits that have been classified as 'worst performing' are refurbished to improve their reliability. As such past performance is not an accurate measure. Nevertheless all pertinent network information will be provided, in a transparent manner, allowing the customer to consider the implication for their organisation, when assessed again this data.

This Information will also contribute to the DNO's calculation of the annual availability payment and/or utilisation payment that it might consider to purchase an FCL service from an existing customer. As outlined in Section 7.3, the requirement for ongoing payments could be avoided by applying this technique to only new connection customers.

As stated previously, there are no fault level issues on any of the Electricity North West networks where Respond trials are taking place, to ensure that if the technology fails, there is no risk of any equipment exceeding its rating. For the same reason FCL service trials will also only be conducted on networks after the fault level has been assessed and confirmed to be well within acceptable limits. Therefore, for the purpose of the trial, protection settings on equipment at these sites will be lowered to facilitate the enablement/operation of the controlling technologies. In the absence of network faults during the trial period, which cause the CB to trip, the project team will artificially simulate a fault level response.

The project team had an aspiration to purchase up to five FCL services, each for a period of up to two years, between May 2016 and April 2018. Lowering the protection setting would have allowed adaptive protection interface technologies, on customers' equipment, to be tested in the event of actual phase-to-phase faults on the HV network, during the defined trial period.

In the absence of HV phase-to-phase faults, activating the enabling technology; the project team intended to simulate the conditions under which the protective relay would operate, to evaluate the technique.

This activity was expected to take place towards the end of the defined agreement term and under these circumstances, the test dates and times would be arranged by mutual agreement with the customer, enabling them to both manage their operational processes and ensure resources are in place to reclose the CB, without delay when the constraint is removed.

Lack of customer interest in the trial and the late agreement of terms to test enabling technologies at two partner owned sites will necessitate this controlled approach to testing the interface during a shorter than envisaged trial period.

Controlled constrains of this nature, would be impossible if the technique was to be adopted into BAU as a fault level mitigation solution; however, for the purpose of the trial, this approach provides a credible means of testing the technologies and is acceptable to customers

Multiple providers and prioritisation of response

In common with Electricity North West's C_2C project (which investigated the viability of new commercial arrangements, in the form of a demand and/or generation response during a system fault), the FCL service raises a number of questions concerning the DNO's ability to host multiple managed customers on a particular network. For instance, involving a situation where two or more customers are potentially able to provide managed fault level mitigation services, on the same HV network.

For the purpose of the trial it is proposed that no more than one customer on one HV circuit will be engaged to provide the service. Theoretically, multiple customers, on a single HV network, could provide a managed FCL service and this would provide the DNO with greater security/confidence in the successful operation of adaptive protection at customers' premises in the event of a fault (refer to Section 5.2).

However, in these circumstances it would not be possible for the DNO to prioritise the order in which each organisation's equipment would be constrained, because the Fault Level Assessment Tool would enable the CBs of all equipment, covered by the various managed agreement on that network, when system fault level is high. As such, all managed CBs would be instantaneously tripped, to halt the associated equipments' contribution to fault current, in the event of a fault.

The DNO would therefore have to consider the medium and longer term benefits of engaging in multiple managed agreements, on individual HV networks, by assessing the security offered by more than one contract, against the technical and administrative complexities of managing these, in addition to the aggregated financial commitment of multiple fixed term payments.

Multiple arrangements are unlikely to present a viable long term, cost- effective solution to fault level mitigation when considered against the overall cost of other techniques, which could include traditional network reinforcement.

Nevertheless, it has not been possible to evaluate the solution's ability to host multiple managed customers on singular networks because of the lack of customer interest in the trial of the FCL service at the date of this report. This consideration will be assessed during the final stages of this study and during the safety case investigation. The commercial template will also incorporate relevant clauses to clarify issues pertaining to multiple agreements.

Fault level contribution of customer equipment

Contribution to fault level at the restricting asset (usually on the primary substation controlling CB) is dependent both upon:

- The contribution from the customer's motor/generator, which is subject to the type and rating of the equipment, and the capacity at which it is operated
- The electrical impedance between the motor/generator and the restricting asset.

Different types of AC rotating plant contribute to fault level differently and the contribution to system fault level from synchronous generators is assumed to be six times the nameplate rating. That from asynchronous and doubly fed induction generators (DFIG) is generally held to be to be twice the nameplate rating. All classes of motors are assumed to contribute the

nameplate rating. Typical fault current contribution (at the customer's point of network connection) is illustrated in Figure 1.

Figure 1

Generator type	**Synchronous**	**Asynchronous**	**DFIG**	**Regulation/ Code of Practice**
Fault level contribution ***(multiplier of MVA nameplate rating)***	6 x	2 x	2 x	CP259
Motor type	**Synchronous**	**Asynchronous**	**Induction**	
Fault level contribution ***(multiplier of MVA nameplate rating)***	1 x	1 x	1 x	G74

Network impedance can considerably reduce a customer's equipment's contribution to fault level at the HV busbar and where a site is embedded at a remote part of a HV circuit, a long distance from a primary substation, the fault current from equipment operated at that location diminishes exponentially as it flows through the network. Therefore, it does not pose the same risk to protective breakers, as generation and large motor sources nearer to the primary substation. As such, deployment of the technique at remote sites does not provide the DNO with the same fault current mitigation opportunities.

Security and resilience

A mechanism is required to ensure that customers cannot disable the relay/CB to prevent operation when it is required to reduce fault level.

The DNO must have confidence that any customer providing a managed FCL service would refrain from any act that could immobilise the operation of the agreed CB, as this might be required, at any time, to reduce fault level on a constrained circuit to prevent the primary switchgear being exposed to potentially catastrophic failure.

However, the FCL service introduces a theoretical but significant risk that a customer could inadvertently or intentionally inhibit the constraint of their equipment by disabling either a relay controlling their CB or simply disconnect the RTU. This is a safety issue that, in the case of the former, the DNO is unlikely to be aware of.

Whilst the DNO would immediately be aware of a communications failure it has little or no control over either scenario. If a customer was deliberately intent on preventing the operation of a CB to constrain their equipment during for example, a business critical period, the DNO would be unable to prevent the action. It is also unlikely that the DNO would have unrestricted access to the customer's switch room to reinstate the enabling technologies.

Penalty clauses should be sufficiently punitive to ensure that customers adopt measures to prevent the unintentional isolation of enabling technologies and deter purposeful tampering.

This risk would apply irrespective of whether the response is purchased from an existing customer, or applied as a new constrained connection. As such, every installation and management agreement, for the provision of fault level mitigation services, should provide:

- A stringent mechanism by which the DNO is assured of control of the CB at all times during the term of the contract.
- Mitigation against early termination, safeguarding the DNO and its network from exposure to unacceptable risk should a customer walk away, or fail to adhere to the

terms of a fixed term managed agreement. Mitigation against early termination of a contract by a customer (who intends continuing to operate equipment contributing to fault level) should include:

  - A sufficient period of notice, allowing the DNO time to implement alternative fault level mitigation measures or conduct any necessary network reinforcement

  - Penalties for the early termination of the managed agreement

- In the event that ownership or occupancy of the customer premises changes during the term of the contract from the providing customer to a third party, who also intends operating equipment that contributes to fault level; then the change of ownership should not impact the managed agreement, which should remain in force and be novated to the new owner on the date that ownership is transferred.

The DNO should maintain the right to disconnect the supply if any of these terms are breached. These terms could be imposed as conditions of a new connections agreement; however, an existing customer is unlikely to accept such clauses when offering to sell an elective service.

In addition to risks around intentional interference, appropriate mechanisms must be deployed to manage a communications link failure, guaranteeing default settings cause the system to fail safe, thus ensuring the service remains available should a fault level response be required. Part of the trial will be to test that adaptive protection on a customer's equipment is enabled if communications fail.

Additional maintenance

Additional maintenance of CBs may be required due to an increased operating frequency. The terms of ownership of the CB under a managed agreement do not change and as such, responsibility for maintenance of the CB remains with the customer or the third party (owner/operator) contracted to undertake this function. As such, this is a consideration for the customer, rather than the DNO. Additionally, the particular complexities of some generators' operating arrangements, particularly in the case of cogeneration plants, can introduce further obstacles in relation to warranty and maintenance agreements. These responsibilities remain with the customer and are discussed further in Section 6.6.

Safety case and post trial analysis

In common with other technical solutions being investigated under Respond, the FCL service is subject to a safety case for the use of current limiting techniques to manage short circuit current on electrical distribution networks. This will consider post-fault operational analysis to ensure the technology interfaces operate as intended and that a high quality service is maintained. Application of the technique as a BAU fault level mitigation solution is also dependent on cost benefit analysis and a carbon Impact assessment. These investigations will be based on trial evidence and inform a buy order of fault level mitigation solutions

6 CUSTOMER DRIVERS AND BARRIERS IDENTIFIED

Direct customer consultation has identified that financial benefits are the only motivating factor in an organisation's decision to consider the provision of a fault current response, and their assessment of reward versus risk is one of the primary barriers in transitioning these organisations from theoretical interest in the service, through to meaningful commercial discussions.

This phase of customer engagement established a number of recurrent concerns, which present insurmountable barriers for organisations that meet the technical criteria, from providing an FCL service, even for a limited trial period.

The loss of critical plant has a major impact on the decision making process that a customer must consider before agreeing to provide a fault level response. Perception of risk and resilience to equipment, processes and wider business operations were cited as the greatest barriers to either commencing or continuing dialogue about specific commercial terms and conditions. Other associated considerations that deterred customer engagement include: the additional costs arising from the loss of production, downtime and overtime to recover lost productivity; the sourcing of additional alternative energy to keep processes operating and the costs of re-energising the plant.

The key concerns are summarised below and discussed in greater detail later in this section.

- Damage to equipment
- Impact on operations
- Unpredictability of the FCL service
- Frequency of curtailment/fault level events
- Acceptability of price point
- Responsibility for reclosing the circuit breaker after the fault has cleared
- Maintenance and warranty arrangements
- Relinquishing control of equipment
- Installation and commissioning downtime
- Other commercial operating arrangements and alternative revenue streams
- Customer confidence in the concept

These barriers and risks are now considered individually:

Damage to equipment (particularly from a crash stop)

One of the key findings of this phase of research is that dynamically braking or 'crash stopping' a large synchronous generator or AC motor represents far too great a risk for the customer. The majority of customers consulted expressed reservation about trial participation, or discounted the idea outright because of perceived risks associated with switching their equipment off instantaneously.

> *"It takes a large generator time to ramp down, how do you switch it off for ten minutes, without doing damage?"*

All rotating plant of this type is protected by some form of electrical or mechanical braking system, which can quickly and safely reduce the rotating speed of the equipment to a stop. This is triggered instantaneously when equipment is operating and its source of power is interrupted, for example, as a consequence of a complete loss of supply to the site. This brake would be activated when the CB, protecting the specified piece of plant, is tripped to provide a fault level response.

One of the overriding concerns of CHP/cogeneration operators was the potential for significant and instantaneous damage to engines/turbines resulting from implementing a crash stop from full load. This concern has in some instances been the result of customers misunderstanding how the technique will operate. Most consulted recognised that dependent upon the particular configuration of their site, the CHP unit could continue to run when a fault level response is invoked; however, it will be prevented from exporting onto the network.

Other organisations had reservations about exposing equipment, particularly CHP generators, to an unpredictable number of crash stops, requiring a complete cold/crash restart, where technical support is not immediately available on site (refer to Section 6.5).

Technical decision makers, representing a number of organisations, estimated that each crash stop could have the effect of reducing a machines operational life by around ten hours, in addition to the exposing the business to additional overall maintenance costs and down time to facilitate this (refer to Section 6.6).

However, the customers consulted acknowledged that this situation could arise under normal G59 conditions, if action was not taken quickly enough to arrange a slower controlled shutdown.

The potential long term impact on equipment was perceived to be less of a risk and more manageable for organisations where technical support is continuously available on site. These customers have the ability to reclose a CB as soon as the DNO removes its constraint and facilitate the 'hot start' of their turbine, before it completely stops spinning. The trial of interface technologies aims to demonstrate that this could be achieved within just a few minutes of the CB being tripped. Where a hot start is possible, it involves substantially reduced costs for the organisation than those incurred from the cold start of equipment. However, the organisations that invest in permanent on-site technical support tend to do so because this provision is critical to their business. These customers typically operate continuous production processes for example in the manufacturing and food processing sectors, where the stoppage of a conveyor line would cause a significant commercial loss (refer to Section 6.1).

These organisations have provided the project team with valuable information and learning but have universally been disinterested in participation of the FCL service trial because the impact of just a momentary constraint to a single piece of critical plant is prohibitive. As such, the target market for the purchase of an FCL service has been identified as I&C customers in the non-manufacturing sector.

However, for certain organisations, application of adaptive protection at the site's primary CB, deployed at the point of network connection, provides a commercial opportunity for the customer which negates any direct impact on their equipment from a crash stop. This is more pertinent to the operators of generators, particularly where the site's configuration allows a fault level constraint to be applied which simply islands the generator. This prevents export but allows their generator to continue running and producing energy; for example, where the organisation consumes the energy its generator produces to meet its own demand and/or where energy can be locally stored, for example using thermal storage.

Operating the protective breaker at the connection point instantaneously prevents the export of electricity and consequently the passage of fault current onto the network in a similar manner afforded by existing G59 relay protection. However, this would also disconnect import, causing loss of supply to parts of the business not served by the islanded generator.

Whilst this arrangement might not be suitable for all organisations, installing remote enabling technologies in this manner may provide a commercial opportunity for customers able to utilise electricity generated from an islanded generator, which might ordinarily have been exported, to build up heat in an alternative manner, for example utilising an on-site storage.

Customers generally accepted that faults on the distribution network would cause the site's primary CB to trip causing all equipment, not protected by an uninterruptable power supply (UPS) or other instantaneous source of back up, to immediately shutdown. Customers recognised that the network operator is unable to guarantee a continuous uninterrupted supply and faults cannot be anticipated; as such, application of adaptive protection on a customer's equipment simply exposes the plant to the potential of an increased number of stoppages. Nevertheless, the indeterminate frequency of these additional shutdowns and the associated costs was a cause of concern (refer to Section 5.2).

> *"Increasing network demand and generation over the next 10 years is likely to increase the present frequency of G59 operation"*

Impact on operations

The premise of the FCL service is that a CB protecting specific AC rotating plant, which contributes to fault current, could be operated remotely to constrain the equipment for just a few minutes. With the exception of an islanded application of the method (as discussed in

Section 6.1), this could be achieved without the need to isolate the organisation's supply from the distribution network; thereby facilitating a fault level response, whilst mitigating wider impact on other business functions.

However, this phase of engagement has highlighted the extent to which organisations' generators and motors are intrinsically linked to many other business functions. As such, curtailing a single but critical piece of plant, even for a short period, can have serious and costly implications. This is particularly the case in the manufacturing sector, where halting a continuous production process is likely to result in the significant of waste of materials, along the entire production line, which might necessitate extensive, costly and time consuming cleaning processes before production can recommence.

> *"A power cut without any notice costs us about 45 minutes start-up time across 10 production lines"*

> *"We need the fewest potential stoppages due to cost of scrap material produced when machines stop due to loss of electricity"*

Other barriers associated with the loss of production, particularly where continuous automated processes are involved include: the cost to the business of staff downtime; additional overtime costs to catch up on production; additional raw material costs to replace those wasted; sourcing additional alternative energy to keep processes operating and the costs of re-energising the plant. One of the most notable concerns was that the method might impact the plant in such a manner that it would be unable to meet order deadlines and breach service level agreement with the end-customer. The unpredictability of events, combined with the lack of flexibility to opt out (Section 6.2) might jeopardise supply contracts, particularly if multiple fault level events occurred, which impacted product/service delivery, over the term of a managed agreement. For the same reason, customers also raised concern about the reputational impact on their business.

6.1 Unpredictability of the FCL service

The service must be continuously available, 24 hours a day, seven days a week because the service would always be required when system fault level is above the switchgear rating. Therefore, under the terms of a managed FCL service agreement, customers would be unable to opt out of providing the service on protected days; restrict the number of occasions that equipment could be constrained each year or withhold provision during business-critical times. This differs from other commercial service available to large users and generators in the competitive energy market (discussed in Section 6.9).

Many of the customers consulted in the study were uncomfortable about the DNO's inability to:

- Accurately predict the number of occasions that the FCL service might be activated each year (refer to Section 6.3)
- Specify exactly when equipment would be remotely constrained.

> *"I would want to know precisely what would need to be switched off, and when; there would need to be a detailed discussion because our plant is too complicated to do this without it being seriously reviewed in detail"*

> *"I would require notification of disconnection; can we specify no-switch off times?"*

A number of organisations expressed an interest in providing the service, as an additional income stream, but only during specific periods, when production or business critical processes were off-line. This was typically when the generator/motor will not be operating and therefore not contributing to fault level.

"Our motors are part of a mixing process which cannot be interrupted mid sequence, it would have to wait until the process was complete - is this possible?"

The majority of customers wanted more information to understand the likelihood and timing of events, to assess how this might relate to loss of revenue through power sales or mechanisms such as the Generator Distribution Use of System (GDUoS) which are passed on to generators via a process of charges and credits.

"I need to understand the duration of outage and loss of CHP financial savings, vs. disconnection revenue".

Customer feedback suggests that the project team's inability to specify the timing of events or the potential number would impede resourcing forecasts and consequently an organisations ability to manage down time.

6.2 Frequency of curtailment/ fault level events

Customers who took part in the survey, and those consulted more directly, expressed nervousness about the number of times that their organisation's equipment could potentially be constrained under a managed agreement.

It is only possible to give prospective providers an indication of the likely number of annual events, based on fault level analysis and the specific fault history of their network. This information offers no guarantee of providing an accurate future forecast of potential activation events.

This was clearly a significant barrier to participation for a number of organisations, as they were unable to conduct an accurate risk assessment, covering the trial period, to ensure that the incentive offered was sufficiently lucrative to offset any potential losses that their business might incur. This is likely to present a greater barrier in a BAU contract covering a much longer term.

"I would want an assurance that the financial reward would compensate my loss"

Other customers were concerned that the DNO might underestimate the number of fault level events that an organisation might be exposed to over the contract period, rendering provision both:

- An unacceptable risk
- Financially unviable as a potential revenue stream, if only a single annual payment was to be awarded simply on the basis of availability. This finding suggests that, in common with the Short Term Operating Reserve (STOR) market (referenced in Section 6.9), both an availability and utilisation payment might need to be applied to the pricing model, to incentivise participation. This would give the customer an assurance that they could expect to receive a fee each time they were called on to provide a fault level response.

Section 5.2 outlines how the frequency of event is likely to be controlled as part of a limited testing regime during the trial period, which is demonstratively more appealing to existing customers and may be influential in securing the purchase of further managed agreements. Nevertheless, it is recognised that controlling the number and frequency of events would be impossible if the technique is adopted as a BAU fault level mitigation solution.

6.3 Acceptability of price point

The project team investigated the most appropriate mechanism for calculating the optimum price point and developed a pricing matrix prior to the survey and before engaging I&C customers directly, to purchase a managed service.

The price point for deploying adaptive protection at customers' premises and the viability of ongoing customer payments (relative to traditional reinforcement and techniques investigated in Respond) is discussed in Section 5.1.

Electricity North West's proposed availability/utilisation payment was indicative and based on the costs of deferring network reinforcement. This was presented to customers, for evaluation, as a suggested starting point for negotiation. It was envisaged that this approach would enable the project team to develop an appropriate pricing model at a price the DNO is prepared to pay and at a level that the customer is willing to accept. The figure did not include fees/costs associated with securing agreements with aggregators/agents.

Regrettably, customer investigations into the pricing mechanism have proven inconclusive. Neither the survey nor direct customer consultation has established a suitable payment framework. It is apparent however, that customer expectations around the fee for providing the service are not founded on their equipment's contribution to fault level, but are based solely on commercial motivation, specifically the financial benefits versus risk and uncertainly.

> *"We would need the financial team to look at contracts to see how beneficial it would really be to us"*

Acceptability of the payment level varied significantly across the entire I&C sector and fluctuated dependent on unique operations and the business model of the organisations consulted. As anticipated, expectations amongst manufacturing industries and those operating continuous production lines significantly exceeded those from the non-manufacturing sector.

In light of the potential financial impact of lost productivity proving an impediment to trial participation; all organisations consulted, were asked to provide a realistic estimate of the cost of a 10 minute constrain to their generator or motor, to assist in validating the pricing model. Responses from those providing an estimate ranged from £1,000 to £100,000, with around 45% claiming each event could have a financial impact of over £10,000.

Customer feedback suggests that the reward is not sufficiency lucrative to entice customers and falls short of the fee they would expect to offset additional maintenance costs or cover contingencies they consider are necessary to provide insurance against the potential risks of loss, damage, disruption and inconvenience. Critically, customers already contracted to other schemes believed that trial participation could expose them to lost revenue or penalties from a third party and consequently, were reluctant to proceed on that basis (refer to Section 6.9).

6.4 Responsibility for reclosing the circuit breaker after the fault has cleared

The FCL service is only required for a few minutes by the DNO to halt a customer's equipments contribution to fault level. Consequently, the DNO's price model to purchase fault level mitigation is based on the short duration curtailment of equipment, because the constraint on a customer's CB will be disabled as soon as fault current is cleared and the network is reconfigured. Fault current is removed in a second but it would typically take between three to ten minutes to reconfigure the system and remove the constraint. This would allow the customer to safely reclose the CB and switch their equipment back on in a controlled manner.

In reality, the customer's ability to operate equipment might take some considerable time, after the network fault has been cleared, as they may not have a local person available who is appropriately authorised to reclose a CB after it has tripped.

Ongoing customer engagement has identified that many organisations lack the expertise or have no 'in house' engineering resource to remedy occasional problems arising with large plant. This function is often managed via third party contracts with experienced operators and

these agreements may provide no guarantee of a response until several hours after the initial request for support.

As response engineers often cover large geographical areas and travel long distances, it could take several hours to reclose a CB after the constraint has been removed. Customers had an expectation that the proposed pricing structure needed to more realistic and reflect the provider's actual down time, in addition to other incidental costs of restarting equipment. However, it was accepted that these considerations are likely to vary significantly between organisations and that it would be impractical to for the DNO to negotiate different and bespoke prices, reflecting customers' individual business models, if the method was adopted into BAU.

6.5 Maintenance and warranty arrangements

Additional maintenance of CBs may be required in response to an increased operating frequency.

Existing customers have an expectation that the payments they would receive to provide a managed service would generate a beneficial income stream, which sufficiently offsets their contingency for risk and all other additional costs that might potentially be incurred from participation, such as additional maintenance costs.

Customers were apprehensive that, should this become a regular occurrence, it could impact manufacturer's service warranties. The motors and generators operated by individual organisations differ considerably from site to site and equipments is typically designed and installed according to the specific needs of the end user. Ownership, operational responsibility, maintenance arrangements and income generation created for equipment also varies and this is particularly the case at CHP sites, where a multitude of complex operating arrangements, involving third parties, can exist.

> *"Would the generators be serviced and any ancillary equipment be looked after by yourselves or would the contract still fall to us? Also would the unit be updated by yourselves and reconnection charges be paid?"*
>
> *"Would Electricity North West feel assured that the CHP was managed by a third party CHP provider? Available revenue would need to allow for these management costs?"*
>
> *"Who will install the disconnection equipment, who will be responsible for maintaining it, who will remove it at the end of a contract?"*

6.6 Relinquishing control of equipment

Customers have exhibited a distinct lack of trust in relinquishing control of their equipment to the DNO and have stated that they would need to be confident about how the remote interface and control system would work before considering FCL service provision.

Installing adaptive protection at a customer's site will give Electricity North West control of a specified CB, allowing it to be tripped remotely, to disable a motor/ generator or part of the organisation's wider installation, as required, to curtail the equipment's contribution to fault current. An automated signal from the DNO's Network Management System (NMS) will apply a lower protection setting when fault level is exceeded. The CB will only trip if there is a fault during this period; however this would occur without any prior notice or customer consultation. When system fault level is reduced, the normal protection setting will be re-applied.

6.7 Installation and commissioning down time

The installation process could potentially involve down time of between a few hours to a number of days. A lengthy installation period is unacceptable to the majority of customers

and even where an extended outage could be accommodated; organisations have an expectation that Electricity North West would cover any lost revenue associated with the halt of routine operational processes.

> *"We would lose electricity revenue for this and we would need to be compensated. It would affect our own customers"*

Technical considerations associated with bespoke technology installation requirements are discussed in Section 5.1.

6.8 Other commercial operating arrangements and alternative revenue streams

There are a multitude of established and emerging commercial schemes and services offering suitable I&C customers a mechanism to generate income or make savings in what is becoming an increasing complex, competitive energy market. These are delivered in a broadly similar manner, involving large users and generators moderating patterns of demand and/or generation to meet the real time needs of the transmission system.

Other more locally operated schemes, such as the FCL service are being introduced or trialled across GB by DNOs, which offer certain regional customers commercial benefits for selling innovative services. These allow the operator to manage its network and assets more efficiently to defer or avoid traditional and costly investment in new infrastructure.

A notable proportion of customers, consulted as part of this process highlighted the conflict that exists with the peak avoidance charging methodology for large users of electricity. Concerns were also raised in relation to the potential curtailment of earning that might arise, if the FCL service prevents customers from providing other commercial schemes, specifically those operated by the National Grid. These conflicts are outlined below and additional information about the most notable services is referenced in Appendix 11.3.

The TRIAD period - peak avoidance

An electricity consumer's bill covers a Transmission Network Use of System charge (TNUoS), proportional to electricity demand during the three highest half-hour peaks of energy demand across National Grid's transmission systems during the most energy intensive period of the year from November to February. These peak half-hour periods are known as 'TRIAD' periods and typically occur when high commercial and industrial demand coincides with the domestic evening peak consumption period, causing an overall spike in energy use.

A significant proportion of the survey population and those engaged more directly, expressed reservation about trial participation on the basis of potential impact on 'TRIAD' charges.

The TRIAD charging system, operated by the National Grid, has been in place since the early 1990s and is targeted specifically at large I&C electricity users. These customers are billed on the basis of half-hour metered demand and their bills are determined by their demand during the three TRIADs.

TRIADs are each separated by at least 10 consecutive days to avoid the possibility of all three falling in consecutive hours or successive days during particularly cold spells of weather. TRIADs are not known in advance. Nevertheless TRIAD forecasting services offered by suppliers and demand-response aggregators, in addition to National Grid's notices of 'tight margin', allows large electricity consumers to reduce load and increase generation during the periods that have a high probability of being declared TRIADs, that year. This charging system has the effect of flattening the demand profile across the whole winter period.

Customer disquiet was particularly apparent amongst generator operators, where a disconnection during a TRIAD period could significantly impact their annual electricity

charges and the revenue generated from the Feed-in Tariff scheme (FiTs) thereby, influencing the level of payment they would expect to provide a FCL service.

> *"I would need to understand the potential likelihood and timing of events in order to understand how this would relate to loss of revenue through power sales eg GDUoS losses and TRIAD charges etc"*

TRIAD management is one of the most lucrative demand-response revenue sources available to large I&C customers and in order to avoid charges, customers must avoid all potential peaks. TRIAD management is a difficult process but it is estimated that large users are required to moderate consumption and export patterns for periods of up to two hours on approximately 15 to 25 occasions each year to avoid penalties.

> *"We would not accept this during the winter when there might be a TRIAD or capacity market event"*

Conflicts with other commercial operating schemes and alternative revenue streams

In addition to the issues around 'peak avoidance', this study has highlighted that I&C customers who theoretically fulfil the criteria to provide a fault level response, are also reluctant to engage because of actual or perceived conflicts with other commercial arrangements.

The structure of the electricity sector is complex, involving the transmission system operator (TSO), DNOs, small and large suppliers, aggregators and other third parties. Large I&C users and generators are becoming increasingly savvy about the commercial benefits available from providing flexible demand and generation to the National Grid, to support its management of the transmission system across GB.

The National Grid offers a range of well established balancing services which can be extremely lucrative to suitable organisations and provide either a revenue stream or a savings mechanism. The schemes most commonly referenced by customers engaged in Respond were: Short Term Operating Reserve (STOR) Demand Side Response (DSR) and the emerging capacity market. These are referenced in Appendix 11.3.

Of the 103 survey respondents across GB, only 14 indicated that they were contracted into other commercial arrangements. However, on the basis of their responses and subsequent feedback from direct consultation with other customers, consultants and aggregators, it is believed that these arrangements present a significant barrier to organisations when considering a FCL service and this is likely to have curtailed dialogue about trial participation.

The viability of a commercial fault level mitigation services, operated locally by a DNO, is dependent, not only on its acceptability to customers (largely driven by risk versus the incentive available), but its ability to integrate with other schemes.

In addition to being financially competitive and integrative, commercial fault level mitigation services must be easily managed. Many organisations do not have sufficient internal expertise about the energy market to make decisions about what schemes are available and which are most appropriate for their particular organisation. As such, generator operators typically rely on suppliers to manage payments under the FITs, Renewables Obligation (RO) accreditation and Power Purchase Agreements (PPA) for exported electricity.

The role of aggregators in the commercial energy market and the trial

Organisations that are able to derive benefit from entering the commercial energy market tend to do so in collaboration with aggregators or electricity supply companies (ESCO) that are able to manage their load and generation capacity as part of a portfolio of sites. This provides the business with predictable income throughout the year via an aggregated, flexible arrangement for which National Grid pays a range of service fees. The aggregators

provide expert guidance about the most appropriate commercial service/s for individual businesses and the most lucrative terms.

Aggregators work closely with their portfolio of customers, often employing complex analytics to identify which processes are business critical and which are time shiftable. This expertise allows both the aggregator and their customers to optimise earning from available revenue streams by providing flexible capacity in addition to improving their environmental credentials by reducing carbon emissions. Critically, the flexibility afforded from being managed as part of a large portfolio of clients generally provides organisations with the freedom of opting out of providing certain services during business critical periods.

Unlike in Electricity North West's C_2C project, aggregators and agents were not directly engaged in Respond to provide a distinct route to market for the FCL service; however, they were encouraged to take part in the survey and a number have been consulted directly to provide feedback and consider the merits for their portfolio of customers. These organisations were furnished with published materials, have been engaged in high level discussion about the technique and were provided with the opportunity of greater involvement to better understand the trial objectives and its commercial/technical arrangements. Whilst some traction was gained, the majority of those consulted expressed little interest.

A small number of I&C customers that had initially shown an interest in FCL service provision, particularly those that have recently connected, or are currently in the process of connecting new generation, decided not to participate in the trial, on the basis of ongoing negotiations with aggregators.

These organisations were reluctant to continue dialogue with the project team and as such, it has not been possible to elicit definitive reasons for their decision to decline trial participation. Nevertheless, it is reasonable to assume that organisations will always seek to generate the greatest possible revenue from their assets in a manner that is not only established, predicable and easily managed, but also provides the greatest flexibility and least perceived risk.

As such, it is likely that these organisations were reluctant to introduce unnecessary complications that might impact contractual arrangements with aggregators and delay or jeopardise services that provide a significant and guaranteed revenue stream.

The project team is continuing to work in collaboration with trusted partners, who have a more direct relationship with customers, associate members and aggregators, to better understand the commercial drivers for customers that currently operate (or are considering participation) in the existing competitive energy market, from concurrently providing FCL services to the DNO. It is hoped that this partner relationship will assist the project team in identifying the commercial barriers and possible synergies that might be achievable in the marketplace.

Operating remote interface technologies with existing automation, installed for other schemes

The commercial schemes, managed by electricity aggregators, necessitate smart remote control equipment at the customer's site. This equipment not only monitors and collects data but automates the market participation process by allowing the customer to shift and modify consumption/generation patterns with little impact on production output.

It has not been possible to test potential synergies due to lack of interest in the FCL service; however, the concurrent provision of an automated STOR service with a managed FCL service is unlikely to be compatible. Whilst the possibility of both services being called upon simultaneously is improbable, it is not impossible and were such an event to arise, the operation of adaptive protection, to mitigate fault level, must always take priority over other commercial services, to prevent catastrophic failure of protection equipment on the

distribution system. For this reason customer's providing an FCL service would be unable to restrict the number of occasions that their equipment is constrained, stipulate protected dates/times, or periodically opt out according to business needs.

For organisations keen to maximise earnings from entering multiple commercial arrangements, a buy order that stipulated the primary activation of adaptive protection for fault level mitigation is likely to present commercial difficulties in negotiations with third parties concerning other schemes.

If such contractual complications are overcome, enabling technologies for adaptive protection at a customer's site would need to seamlessly integrate with existing automation technology, installed by third parties.

Impact of other commercial schemes on proposed payment structure

Customers that are able to exploit their assets, to generate revenue or make savings, in the existing competitive energy market appear unwilling to jeopardise an established, secure and guaranteed income stream buy exposing their organisation to a new and untested commercial arrangement.

STOR and TRIAD management can be operated together and it is estimated that organisations operating a 1100kVA generator, providing 888kw of energy generation might expect to create revenues of approximately £12,000 per annum under STOR, or £23,000 per year in savings under TRIAD, depending on certain caveats such as postcode.[1]

According to Louis Burford, UK vice president at REstore, providing primary reserve can earn a company between £50,000 and £75,000 annually, and has the smallest impact on an organisation's operation, as a call to turn down demand or an activation event, typically lasts no longer than five minutes.[2]

6.9 General customer confidence in the concept

It was anticipated at the outset of the project that Electricity North West would have entered a managed agreement with a minimum of one demand and one generation customer and now be mid way through evaluating live trials of the FCL service with these customers.

Section 7 of this document outlines the current status of negotiations to purchase the requisite number of managed agreements. As at the publication date of this report, retrofit interface technologies have yet to be installed at any site to enable a fault level response at a customers' premise.

As such, it is not currently possible to evaluate industry confidence in the technical arrangements that will be deployed by Electricity North West to facilitate the FCL service.

However, terms are agreed to commence trials at two partner site and feedback concerning technical and commercial arrangements will be documented in the customer final report, due to be published in May 2018, which will be considered in conjunction with a safety case and other post trial analysis.

[1] Source: http://www.generatorassociates.com/STOR.htm

[2] Attributed to: https://www.raconteur.net/sustainability/demand-side-response-changing-dynamics-of-uk-energy-market

7 MEETING SUCCESS CRITERIA – PURCHASE OF THE MANAGED SERVICE

7.1 Acceptability of the FCL service commercial template

One of the key outputs of the project was to develop appropriate commercial arrangements and contract templates for FCL service provision. Model commercial contracts, based on a variation to the National Terms of Connection (NTC) have been produced for existing and new connection customers, which are designed to be transferable to other GB DNOs.

The bilateral FCL service installation and management agreements are published on the project website. The regulatory and legal necessity for specific clauses to protect the network operator, its network and the customers' served, prevents significant material changes to the document. However, the project team have worked in collaboration with Electricity North West's legal department and the legal representative of project partner, United Utilities to assess the suitability of the templates.

During this process, the partner highlighted specific terms and clauses that were deemed disagreeable and this delayed formal agreement of the partnership agreement.

These issues have been resolved and terms for the trial of an FCL service, to test interface technologies, at two of the partner's sites have now been agreed. However, this has involved fundamental changes to certain liability and indemnity clauses. These refinements to the commercial template provide a means of testing adaptive protection on a partner's equipment, under carefully managed and controlled trial conditions. This has imposed certain limitations on the delivery team and restricts the trial period to test technologies, which is considerably less than originally envisaged.

The required modifications to the contract template highlight issues with the overall acceptability of the commercial contract, particularly to existing customers who have no obligation to agree to terms, as they would elect to provide a voluntary fault level response to the DNO.

It would be impractical for the DNO to make similar modifications to the legal framework of a BAU contract and as such, it is anticipated that certain liability clauses are likely to present a barrier to existing customers when considering selling the service.

Considerations about specific terms and conditions is less likely to be a barrier if the method can be applied as a constrained connection, which offers a customer a much quicker and lower cost connection than a traditional quotation. This is discussed further in Section 7.3.

All directly engaged customers have been furnished with a copy of the model contract template and encouraged to provide feedback. Most committed to sharing the document with their respective commercial and legal teams. However, despite repeated attempts to re-engage these customers, most have been unwilling to enter into further dialogue and therefore, wider learning about acceptability of the management agreement, in its current format, is limited.

7.2 Current status of FCL service contracts with trial participants

The main focus of this phase of customer engagement has been to secure the purchase of a FCL service from at least one Electricity North West demand customer and one Electricity North West generation customer, to demonstrate: the route to market, the price point and significantly, the safe implementation and operation of the interface technologies that facilitate the response.

In addition to securing terms to commence trials at two partner sites, the project team is now close to finalising a managed agreement to test the commercial and technical elements of

the FCL service with a large greenhouse operator in the South Manchester region, at a site serviced by a 3.3MW CHP plant, with a gas fired engine. The break fault level contribution from this customer at the 11kV primary substation busbar is ~1.1kA.

This commercial grower is keen to participate, technical site visits have been conducted and all parties are working closely to agree terms; however, the customer's participation is subject to the strict condition that the managed agreement will not extend into the TRIAD period. The payment negotiated for a limited trial participation period significantly exceeds Electricity North West's estimate of the cost that it would be prepared to consider to secure fault mitigation services under BAU conditions, for a generator contribution to fault level of this magnitude.

Active participation in the trial, for a finite period, does not present this customer with any significant concerns regarding actual or perceived risk to equipment, processes or productivity because of the nature of their operation. It is also expected that their generator will continue to operate safely, in an islanded manner, when the fault level response is activated. Furthermore, the proposed trial period is restricted to summer months and therefore affords the least likelihood of weather related network faults, which might result in activation of the fault level response. As such, this limits the customer's equipments exposure to a constraint and consequently, it is likely that enabling technologies will be tested in a controlled manner, in consultation with the operator, at a time and date of their choosing.

Nevertheless, in common with ECP and survey feedback, this customer has an expectation that the requisite payment should provide a reasonable amount of contingency for incidental costs. These cover additional maintenance, inconvenience and standby fees associated with 'off-site' authorised personnel attending, to reclose the operated CB and switch the generator back on. As previously stated, the customer's risk is minimal; however, the agreed payment of £15,000 for a trial period lasting no longer than four months incorporates a customer driven risk apportionment, with an additional expectation of compensation actual loss or damage was to occur.

> *"We have boilers to replace the engines, but we put ourselves at unnecessary risk if the boilers have a mechanical failure if this occurs, additional compensation would be required"*

As such, the payment for this limited technology trial is greater than had been anticipated or that the DNO might reasonably be prepared to pay for a BAU service, as other fault level mitigation techniques are likely to be more cost effective, create more headroom and offer the DNO greater security.

Negotiations are also taking place with a health care provider, currently in the process of installing new generation at a HV connected site within the project timescales.

As stated previously, Electricity North West has now agreed terms to commence trials of the technical interface at two sites owned and operated by the Respond project partner, United Utilities. Both parties are working together to install retrofit adaptive protection on electrical machines at these sites. The partner will collaborate with the delivery team to develop robust 'devise installation procedures' and guidance for future FCL service providers as part of this process.

The four networks in question are not subject to a system fault level issue and therefore, for the purpose of the trial, protection settings on the CBs connected to generators/motors will be lowered, to facilitate tests of the enablement and activation functions of the remote interface and associated communication link. In the absence of network faults during the agreed trial period; equipment will be tested by artificially simulating the conditions under which the protective relay in the CB would be operated under BAU conditions.

Commercial learning from this ongoing phase of engagement will be more thoroughly documenting in the final customer report in May 2018.

7.3 Potential for application of the method as a constrained connection agreement

Electricity North West routinely provides a constrained connection quotation in response to applications for the connection of new DG onto its distribution network, which isolates the customer's export capability in the event of a network fault.

To date it has not been possible to secure a managed agreement with a new customer. However, theoretically, offering an alternative constrained connection, specifically to mitigate fault level, could be accommodated by adopting a similar mechanism to the existing protocol for DG connections, now firmly embedded in Electricity North West's BAU processes (refer to Appendix 11.2). This would appear to be the most reasonable and fair approach, as the new generation customer is responsible for adding to system fault level. As such, this organisation carries the risk of curtailment when a network fault occurs and system fault level is high.

The customer would, as is currently the case, have the option of requesting an un-constrained connection, which would involve greater cost and delivery timescales from the requisite reinforcement. Nevertheless, this study has demonstrated that a traditional connection is likely to be more appropriate for some organisations.

Application of the FCL service in this manner provides a commercial solution to fault level by offering customer choice and for new generation customers, effectively operates as an extension of existing G59 regulations. It also negates the requirement for ongoing payments by the DNO.

It is assumed that constrained connections will be offered only to customers applying for a new connection (including the addition of new generation or large motor load to an existing installation) on the basis that the customer's connection adds to overall system fault current, resulting in higher fault level.

As such, it would be impractical and unnecessarily costly for the DNO to identify and approach existing customers on the network, to offer a managed FCL service, to accommodate a lower cost and expedited connection for a third party. This situation would also be impractical to administer in terms of fault level cost apportionment, which is referenced in Section 5.1.

There may be a requirement to limit fault level constrained connection offers to specific applications where, because of the proposed connection point and the size and type of generator/motor, potential fault current contribution will be significant and thus create a fault level issue.

There may be less benefit for the DNO where customers apply to connect embedded generation, in outlying positions, on unconstrained networks and where the type of equipment and the effect of impedance will have little effect on overall system fault level. These considerations will be subject to governance, which places a requirement on the DNO to provide the lowest cost design offer for all connection applications.

8 LESSON LEARNED

8.1 The DNO community must develop greater commercial understanding

The introduction of DG, renewable energy sources and the emerging energy storage market presents DNOs with enormous challenges. The traditional DNO model is moving towards that of distribution system operation, which will have significant consequences for the

operation and maintenance of networks; the customers they serve; and the commercial services that will become necessary to provide choice and flexibility in the management of these networks. DNOs have visibility of the capacity requirements and generation profiles of I&C customers but traditionally have had little need to understand the needs of the organisations they serve, or their commercial drivers.

The challenges of transitioning customers from an expression of interest, to active participation in the FCL service trial have highlighted that DNOs must develop a greater commercial awareness of businesses' in their target market when introducing new services, in an established and rapidly changing energy market. The loss of critical plant, even for a short duration, can have a significant impact on a business. An assessment of risk verses the incentives and saving available will be fundamental in an organisation's decision making process when considering any elective commercial service.

Potential conflicts with other commercial arrangements and industry players in the commercial services market have been identified as a significant barrier to participation in the FCL service trial. This highlights that greater commercial acumen is required in the DNO community, to better understand the acceptability of this type of scheme amongst customers that are already well positioned to offer other lucrative commercial services, to third parties, in an expanding and competitive marketplace. Whilst it appears that there are potential conflicts, equally there could be possible synergies which warrant further investigation.

8.2 It is not possible or appropriate to persuade disinterested customers to engage in schemes they perceive are unsuitable for their organisation

The use of trusted partners to capitalise on existing third party relationships provides no guarantee of successfully engaging customers if they are fundamentally averse to a proposition.

The time of key decision makers in the target market for FCL service provision is extremely valuable. Whilst the use of trusted third parties provides a platform to introduce a new commercial model to key industry players; it is extremely difficult to gain further traction if the benefits to an organisation from providing an elective service are tenuous, divert key personnel from their day to day commitments and introduce unquantifiable risk to the organisation.

Acknowledging when to cease attempts to engage customers

New commercial techniques may provide a DNO with a credible solution to a network problem; however, it is important to recognise that these opportunities may not be appropriate for the customer.

Whist it is important for DNOs to adopt an engagement strategy which encompasses all reasonable measures to establish key commercial barriers, in order to better understand decisions not to become involved; any research must respect customers' decisions to decline entering into dialogue or ceasing further contact about an optional proposition.

It has been difficult to generate interest in the FCL service amongst I&C customers generally, and from the target, non manufacturing sector, specifically. The project team has established a number of explanations as to why customers have been disengaged and these reasons include beliefs that the technique is unattractive, unsuitable or not financially viable for certain organisations. However, the commercial learning could have been enhanced from engaging with a larger sample of customers, had this been possible. Nonetheless, it is important to cease proactive and repeated communications when customer indifference becomes apparent, to negate any suggestion of harassment; negative impact on the project; or an adverse affect on the reputation or credibility of Electricity North West and its project partners.

9 CONCLUSIONS

The evidence contained in this document demonstrates that whilst a theoretical market for the FCL service exists in specific sectors; the reality is that actual or perceived risks present insurmountable barriers, which have been an impediment to large demand and generation customers providing Electricity North West with a fault level mitigation service via this method.

Both the DNO and its customers are faced with a number of technical and commercial issues that present varying degrees of concern and must be overcome before the terms of a managed agreement are acceptable to both parties. These technical and commercial considerations introduce questions about the suitability and applicability of deploying adaptive protection at a customer's site.

These issues must each be considered individually and assessed against alternative fault level mitigation techniques that might be more effective, deployed more quickly and securely at a secure DNO site (typically a HV substation, over which the network operator has complete control).

This viability assessment should compare the overall installation costs and fixed term payments associated with purchasing a FCL service, against the capital investment associated with deploying other methods, the lifetime benefits to all customers, specifically in relation to how CCCM fault level apportionment rules are applied. Critically, these considerations will consider the safety case and factor in the fault level headroom created by each technique.

It has not been possible to establish a common opinion to determine the optimum price point that is likely to be acceptable to customers; however, survey analysis and direct customer engagement has confirmed that payment aspirations are high, but inconsistent across different organisations and sectors.

Customer motivation is linked to achieving optimal earning potential, assessed in relation to the risk the method might present, which is unique to individual organisations. However, customers have not committed the time to conduct a rigorous benefit analysis to support assertions. Unlike the DNO's calculation, the customer's assessment of an appropriate price point has no basis on their equipment's actual fault current contribution.

Survey responses suggested that take up might be achieved by offering a financial incentive of up to 10% over the tested price point of £1,769 per MVA of contribution to fault level reduction, if combined with a short duration contract of only one year. Direct customer engagement indicates that this response could be inaccurate, with customers largely unwilling to engage, even to discuss a mutually agreeable incentive. Those that have engaged in meaningful dialogue expect a payment which is significantly greater than the indicative £/kA per event or £/kA per contract figure.

Research has established that expected payments will vary according to the contract period, the market sector and the specific demands of the provider and whilst it is impractical to offer bespoke pricing models, the DNO should be prepared to negotiate with a prospective provider if purchasing a FCL service from a specific customer affords the most effective mitigation technique.

However, the purchase of a FCL service, from an existing customer, is likely to cost considerably more to apply than other solutions to fault level, investigated in the Respond project, when final viability studies are complete. As such, buying a fault level response from existing generation or demand customers is unlikely to provide DNOs with a viable, reliable, cost effective and credible long term solution to the problem.

Nonetheless, the solution does provide an opportunity for a new constrained connection agreement that could mutually benefit both a DNO and its customers in the future. A constrained connection of this type might facilitate new generation connections onto networks approaching fault level limits more quickly and cheaply than traditional reinforcement; thereby giving customer the opportunity to make a connection in a desired location, where costs and timescales would otherwise be prohibitive.

For the reasons outlined in this report, a constrained connection of this type will not be suitable or appropriate for all customers proposing to connect large motors load or generation. This arrangement is likely to be more acceptable to new generation customers that are able to continue operating plant, in an islanded manner, when a fault level response is activated.

However, by providing customers with a choice, they can evaluate the benefits of a speedy constrained connection, in a desired location, against the risks particular to their specific organisation. Application of the FCL service as a constrained connection agreement would also negate any complex negotiations to agree terms because all clauses, based on a variation of the NTC, would be non-negotiable.

This arrangement allows the DNO to fulfil its obligation to facilitate the connection of DG by providing a financially viable connection mechanism, without any requirement for ongoing customer payments. A new constrained connection agreement of this type effectively represents an extension of existing G59 regulations for generation designed to run in parallel with the distribution network.

As such, whilst a constrained connection agreement provides a theoretical commercial solution to limiting system fault level, this research highlights that the technique is acceptable and suitable for only a small number of customers. The method will also only provide the DNO with a solution where a customer, operating suitable plant, is in an appropriate location to make a significant contribution to the fault level; and only then when the DNO has confidence that this customer can always be called upon to provide the response.

In conclusion, installing adaptive protection at a primary substation will always provide the DNO with greater headroom and at less cost than buying a fault level response from a customer. Adaptive protection at a substation also provides the DNO far greater security and negates uncertainty about long term customer commitment to the method.

10 NEXT STEPS

As part of the trial, all participating customers and project partner, United Utilities, will be consulted and provide feedback about their experience of taking part in the trial to support commercial learning. This research will allow the project team to better understand the viability of the method, from the customers' perspective by gaining insight into the actual impact on equipment and the organisation as a whole. This study will be undertaken by Impact Research and will be documented in a subsequent report, due to be published in May 2018. This will provide a final assessment of the applicability of the solution and document additional learning on how to best to engage with customers for FCL service provision. It will include FCL service contract templates and disseminate the most effective route to market for these new commercial arrangements with the DNO community.

Electricity North West will continue to collaborate with its project partners to identify up to a maximum of five demand or generation customers to trial the technical and commercial elements of the FCL service, to supplement project learning.

The project team will continue to engage with customers, their agents, aggregators and other forums to better understand the commercial drivers, barriers, synergies and financial viability for customers that are both suitable and potentially able to provide commercial fault

mitigation services; who might already be operating (or considering participation) in the competitive capacity and balancing market

In common with the other techniques being investigated as part of Respond, the FCL service will be subject to post-fault operational analysis to ensure the technologies operate as intended and that a high quality service is maintained. The FCL service will also be subject to a safety case for the design and operating arrangements for the technique, which takes trial evidence into consideration. A cost benefit analysis and a carbon impact assessment will also be conducted, to inform a buy order of the three fault level mitigation solutions being trialled under Respond and this learning will be documented in individual reports and the project closedown report, due to be published in October 2018.

11 APPENDICES

11.1 Respond customer survey – method, challenges and key lessons learned

The project team had an aspiration to recruit approximately 750 I&C demand and/or generation customers, from across GB, to participate in a large scale survey. This was expected to attain meaningful results from a sufficient number of organisations that theoretically met the criteria to provide an FCL service.

The project team considered every possible source of customer data, to maximise opportunities for recruiting the optimum number of survey respondents. These included:

- Public domain databases of CHP, anaerobic digestion and hydro electricity plants across the UK
- Electricity North West generation database, specifically: Mini, micro, small and medium sized CHP plants located within North West England
- Databases holding details of all HV connected generation /demand customers on Electricity North West's network and those operating suitable plant on private networks connected in parallel to the distribution system
- Databases on new applications for connections (meeting the requisite criteria) to the Electricity North West network
- A sample of customers that had pre-registered their interest in taking part in the survey /trial having read advertorials, newsletters and other proactive communications
- Organisations that had been proactively approached by the Respond project partners, ADE and ENER-G.

This combined data set consisted of over 1,600 organisations from across GB. The complexities of initially promoting interest in both the technique and the survey, then subsequently engaging with the appropriate technical and/or commercial representatives in suitable organisations presented a significant challenge. This was time and resource heavy to administer. As a consequence, this activity incurred additional and unforeseen costs. It also resulted in an extension to the proposed survey fieldwork period, which was unavoidable, to secure a sufficiently robust number of participants.

All potentially suitable new HV and EHV customers, including those recently connected and those progressing through the connection process were approached to participate in the survey. However, the market research provider was unable to generate sufficient interest to secure any completed surveys from this sector.

The project team's initial criteria for participation in the survey and was restricted to I&C customers connected to HV networks in GB, operating a single large AC synchronous rotating machine, connected in parallel with the distribution network. A further criterion was generation or consumption capacity of between 1MW and 7MW.

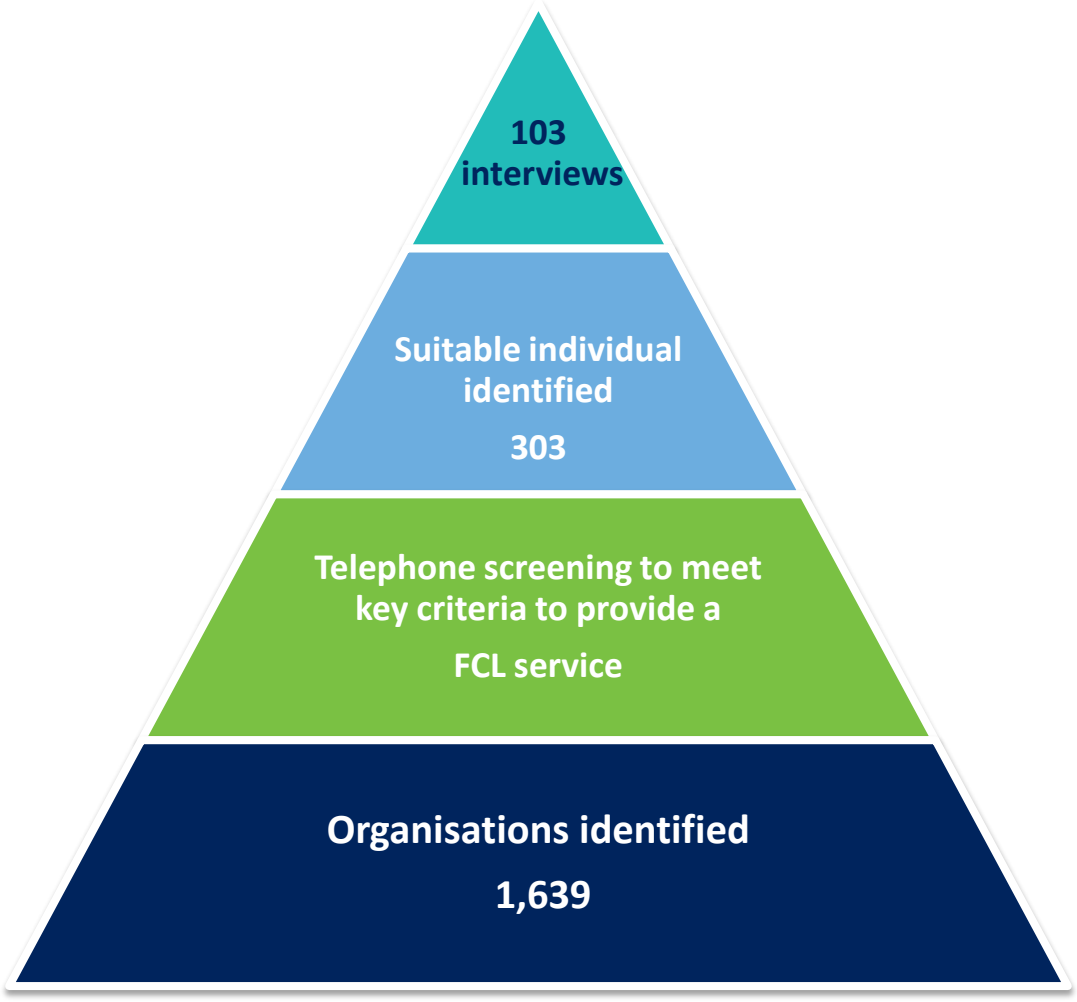
However, when the challenges of recruiting survey participants became apparent, the criteria was extended to include both HV and EHV connected customer's operating equipment with capacity ranging from 500kVA to 15MW. The survey was also opened to customers operating multiple smaller motors with a combined output of above 500kVA, provided these were connected to a common CB.

A lengthy screening exercise was conducted to establish organisations that satisfied the technical criteria to provide an FCL service and who were prepared to provide the details of a suitable representative to participate in the research. These representatives were subsequently sent a unique link to an electronic survey.

Despite extending the survey timeframe and the technical criteria for respondents, the convergence rate was poor. This was improved by repeatedly contacting the individuals identified during the screening process and extending the offer of telephone assistance to administer the survey.

However, improvements in the convergence rate are more likely to have been influenced by the enhanced incentive offered and the introduction of a prize draw, aimed at maximising the number of responses. By adopting this approach, the project team was able secure 103 completed surveys, which represents a convergence rate from recruitment to completed survey of 34%.

The final total of 103 surveys provided a statistically robust number of responses for meaningful analysis; however, the time and resources involved in achieving this convergence was not cost effective and demonstrates both the challenges of engaging I&C customers, along with the creatively and costs associated with research of this type, involving this particular market sector.



Key commercial learning from the customer survey

Results of the customer survey identified that, theoretically, a market exists for the method, thus proving one of the key project hypotheses. However, appetite for the service is limited and restricted to certain I&C sectors; specifically, non-manufacturing industries and organisations that are able to cope with having large rotating plant instantaneously constrained for short durations of around 10 minutes, without this having any significant impact.

The survey analysis identified that the optimal FCL service contract is likely to be short term (customer's expressed a preference for a one year agreement). This reflects similar findings in C_2C research. Whist a limited term contract is appropriate to trial the technique it is unlikely to be appropriate as a BAU proposition, unless implementing the method as a temporarily measure, provides the DNO with short term network resilience, whilst planning and deploying a more appropriate fault level mitigation solution.

Respond survey responses suggested that significant gains in take-up could be achieved in the target market by offering increased payment per event (PPE) of +10% of the financial incentive tested in a choice bases experiment, which was embedded within the survey. Details of indicative offerings are outlined in Section 5.1 of this report.

One of the key findings of the survey was that customers are sensitive to other commercial forces and averse to perceived risks from their organisation providing an FCL service. These barriers are considered in greater detail in Section 6 of this report.

Predictably, analysis suggests that organisations are motivated by financial gain and greater potential take-up might be achieved by increasing the suggested availability payment and placing a limit on the maximum number of events per year; however, in a BAU situation, this would not be practicable for the DNO.

11.2 Constrained connection agreements

From July 2016, all customers applying to connect DG (above 200kW) onto Electricity North West's network have been routinely offered a 'managed connection', to mitigate the need for reinforcement.

A constrained connection, sometime referred to as a 'flexible' or 'alternative' connection, allows the generator to export up to an agreed limit, under certain conditions, ie when the network is operating 'normally'. However, under abnormal conditions, typically because of a network fault, the generator's export is constrained, to an agreed level.

These connection offers are considerably cheaper than the equivalent non-constrained quotations, which are more likely to require network reinforcement, ie new assets, to support a connection that allows the generator to export unconditionally.

New connection customers can still request a non-constrained offer; however, these are not only more expensive, but generally take significantly longer to deliver because of the time taken to plan and complete network reinforcement works, to accommodate the connection. These works are also recognised to be extremely carbon intensive.

Electricity North West constrained connections allow the isolation of export capability, to ensure it is able to continue supplying electricity in the event of a network fault. Typically this is managed via a CB, which the DNO can control and trip remotely during fault conditions, ensuring the generator remains 'off' until either the network returns to 'normal' or the DNO deems it appropriate to switch the generator back on during the fault.

11.3 Commercial arrangements

Capacity market

The Electricity Market Reform (ERM) programme aims to deliver investment in new technologies to deliver carbon energy, in an affordable, secure and sustainable manner. The reform has introduced new market arrangements in the form of the Capacity Market. This is open to all capacity providers and offers a steady, predictable revenue stream on which providers can base their future investments. In return for Capacity Payments revenue, providers must deliver energy at times of system stress, or face penalties. Potential providers secure the right to receive capacity revenues by participating in a competitive auction, which sets the level of capacity payments. The National Grid acts as the delivery body for these new market arrangements and further information is available on their **Electricity Market Reform** webpage.

Short Term Operating Reserve (STOR) market

Customers operating various forms of generation can tender to participate in National Grid's STOR market, as can organisations operating energy-intensive processes, which can be interrupted for short periods,.

Participating organisations deliver this service by reducing their demand or increasing generation with around ten minutes' notice and they are required to sustain this change for approximately one to two hours. Organisations can received both an availability payment (£/MW/h), payable because their site is ready to respond to a STOR event, in addition to a utilisation fee (£/MWh) for a delivered increase in energy generation and/or reduction in demand.

Demand Turn Up

This is also sometimes referred to as a 'footroom' service, which benefits organisations able to increase consumption or reduce generation when there is excess energy flowing across the transmission system, for example when wind output is high.

A number of other established National Grid balancing schemes are available to organisations, able to provide demand side service, that potentially conflict with FCL services. These include: STOR Runway; Firm Frequency Response (FFR); Frequency Control Demand Management (FCDM) and Fast Reserve services. Emerging services include Enhanced Frequency Response. These schemes are explained on National Grid's **Balancing Services** webpage.