
PPA energy

Planning Energy
for a Sustainable World

# NIC Competition
# Final Interrogation Report

# Enhanced Frequency Control Capability (EFCC)

## submitted by

## National Grid Electricity Transmission PLC

**Submitted to: Ofgem**

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**CONTENTS**

# 1 Project Summary

Enhanced Frequency Control Capability (EFCC) focuses on the development and demonstration of a new monitoring and control system that will contribute to solving the problem of frequency control on the GB network with an increasing penetration of renewable generation. The control system will be used to demonstrate the viability of obtaining rapid frequency response services from sources such as solar PV, storage and wind farms. The method will also demonstrate the coordination of fast response from demand side resources (DSR), and fast start up from thermal power plants.

The method proposed addresses the problem of controlling system frequency as system inertia reduces, the consequence of conventional generation being replaced by renewable generation on the system. Without EFCC, National Grid, the sponsoring Network Licensee, claims that the cost of controlling frequency will rise by £200m - £250m by 2020. Savings of £150 - £200m per year by 2020 are predicted using the method.

National Grid (NGET) states that EFCC will include developing a fully optimised and coordinated model that will ensure that an appropriate mix of response is utilised. A commercial framework enabling the response from a variety of sources to participate in the balancing mechanism will also be developed.

Project partners comprise Alstom (the technology provider), Belectric (providing battery storage and PV power plant response), Centrica (providing wind and CCGT power station response), Flexitricity (a demand side response provider), and the Universities of Manchester and Strathclyde.

The total project cost is £9,603k and the NIC Funding request is £7,239k.

NGET is making a compulsory contribution of £823k to the project, but no extra contribution.

A total of £1,371k of external funding is being provided from the project partners.

## 2 Assessment Against Criteria

### 2.1 Summary of Assessment Criteria

The criteria against which each submission will be assessed as outlined in the Electricity NIC Governance Document:

(a) Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers;

(b) Provides value for money to electricity transmission Customers;

(c) Generates knowledge that can be shared amongst all relevant Network Licensee;

(d) Is innovative (ie not business as usual) and has an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness;

(e) Involvement of other partners and external funding;

(f) Relevance and timing;

(g) Demonstration of a robust methodology and that the project is ready to implement.

## 2.2 Criterion (a): Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers

### 2.2.1 Key Statements

*Carbon Claims*

NGET explains that for a low carbon energy sector to develop it is vital that renewable energy sources are able to connect to the grid. Easing the process whereby new renewable energy sources can connect to the grid is cited as a key objective for the company overall.

It is stated that EFCC will play a vital role in enabling the GB system to be run securely and efficiently as NGET connects increasing volumes of renewable energy.

No quantified carbon reduction claims are made, however energy savings are presented based on avoided curtailment of energy from low carbon sources.

*Environmental Benefits*

Environmental benefits from the project arise from the way that it facilitates the connection of additional renewable generation to the grid system and potentially reduces the reliance on fossil-fuelled generation to provide system inertia and fast response services. Specifically, it is claimed that the project addresses:

- the removal of barriers to a high penetration of low-inertia renewables evolving, by developing both a technical approach and a market solution for locationally diversified frequency response services;
- the need to avoid the dispatch of large amounts of conventional fossil-fuelled generation, particularly at inefficient levels of output, to increase system inertia and provide the fast response services needed to secure the system; and
- the development of market-based incentives for stakeholders, including the demand side and renewable generators, to participate in the provision of services normally obtained from conventional generators.

*Quantitative analysis of Carbon/ Environmental claims*

The carbon and environmental claims are presented as a saving in energy from renewable sources that would be curtailed without the EFCC project. The figures presented suggest that 19 x $10^9$ kWh (19,000 GWh) of renewable generation would be curtailed in 2020.

*Robustness of Financial Benefits*

A saving to the end consumer of £150-200m per annum is claimed from the implementation of the project.

The level of cost savings achievable depends on which of three options for addressing the problem of reduced system inertia and the need for fast response would otherwise be pursued. The savings quoted are:

- compared with the costs of constraining large generation and interconnectors down to reduce the "largest loss" that needs to be covered in a lower inertia situation, a reduction of £121m per annum by 2020, £258m per annum by 2021;
- compared with constraining generators on to secure a higher level of inertia on the system, a reduction of £590m per annum by 2020;
- compared with increasing the volume of response purchased from conventional power stations, a reduction of £200m per annum by 2020.

*Capacity released and how quickly (if applicable)*

There is no transmission capacity released as a result of this project.

*Replication*

A key element of the replicability of the project hinges on the development of the commercial arrangements to enable renewable generators to participate in the balancing mechanism in the future.

### 2.2.2 Challenges and Potential Shortfalls

| **Criterion (a): Accelerates the development of a low carbon energy sector and/or delivers environmental benefits whilst having the potential to deliver net financial benefits to future and/or existing Customers;** | |
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| Sub-criterion (a.i)- Carbon claims | Challenge (a.i).1: There is no information provided as to the scale of carbon reduction that could be achieved through this project. Some indication of the potential carbon savings from the displacement of fossil-fuelled generators as the primary source of inertia and response services would be beneficial. |

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| | Answer (a.i).1: In appendix 1, the potential for avoiding the curtailment of clean energy resources because of low system inertia is presented. This is the first and most important environmental benefit of EFCC.<br><br>In addition, the fast response can result in saving on carrying response on fossil-fuelled generation. The existing frequency control market is heavily based on fossil fuel generation technologies (both primary. high, and secondary response). To assess the environmental benefits benefits of EFCC, the primary and high response service are more relevant. It must also be noted, that given that when we "hold" response, we do not actually generate power, instead of the $CO_2$, $NO_x$ levels are used (particularly important in case of CCGTs) and it has direct relationship with the output level. The savings made on holding slow response are directly linked to savings made on NOx emissions because of:<br><br>• Avoidance of potential energy constraint of fossil fuelled power plants for the purpose of providing frequency response; and<br><br>• Better operating point of synchronous power plants (reduced emissions) when plants are operating at optimum output levels rather than being constrained to operate at lower output level to hold response -> reducing the loading level on CCGTs for example will have an impact on the efficiency and the NOx emissions.<br><br>In order to quantify the exact emission savings, as a result of better operating point of thermal plants, the emission curve of individual units (including future units) will be required. This information is not available to National Grid, and therefore we can only make an estimation of the potential savings based on the total additional volume of response which will be saved: |

| | 2020/2021 in Gone Green Scenario(Calculated) | 2020/2021 in Slow Progression Scenario(Calculated) |
|---|---|---|
| Volume of Holding Response (TWh) | 33.9 | 32.2 |
| Saving (TWh) | 20.2 | 18.5 |

<table>
<tr><td></td><td>Conclusion (a.i).1: Whilst the principles on which the assessment of the differing levels of response requirement is based are clear, the method of calculating the volumes given above is not transparent and therefore it is not possible to comment on their accuracy.</td></tr>
<tr><td>Sub-criterion (a.ii)-Environmental benefits</td><td>Challenge (a.ii).1: Insufficient information is provided as to the volume of response services that are required in the future Gone Green and Slow Progression scenarios and the amount of response from conventional generation that could be displaced if EFCC proceeds. Whilst in principle it is clear that environmental benefits will accrue from the reduced reliance on conventional generation if EFCC succeeds, the quantities of conventional generation displaced require significant clarification.</td></tr>
<tr><td></td><td>Answer (a.ii).1:<br><br>The volume of response services for Gone Green and Slow Progression scenarios can be estimated as below:<br><br>
<table>
<tr><th></th><th>2013/2014<br><br>(Actual)</th><th>2020/2021 in Gone Green Scenario(Calculated)</th><th>2020/2021 in Slow Progression Scenario(Calculated)</th></tr>
<tr><td>Total Volume of Holding Response (TWh)</td><td>13.7</td><td>33.9</td><td>32.2</td></tr>
</table>
The amount of response from conventional generation that could be displaced is estimated as below:<br><br>The quantities of volume of conventional response saved can be derived as follows:<br><br>
<ul>
<li>Amount of displaced holding response from conventional generation (Gone Green)=20.2TWh</li>
<li>Amount of displaced holding response from conventional generation (Slow Progression)=18.5TWh</li>
</ul>
<u>Reason:</u> The assumption behind the calculated above figures is that the response quality will have the inherent delay of 2 seconds. This means that in order to provide sufficient response to the grid when the rate of change of frequency is high, more volume of slower response must be held (inefficient).</td></tr>
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| | Conclusion (a.ii).1: It is unclear how the 20.2 and 18.5 TWh figures have been derived and in particular whether the assumption that these proportions of conventional generation can be displaced are reasonable. Whilst it is understood that complex models are required to derive these estimates, greater transparency in these calculations is required to give confidence in the predictions of the overall project benefits. |
| Sub-criterion (a.iii)-Quantitative analysis of Carbon/ Environmental claims | Challenge (a.iii).1: There is insufficient information provided to validate the savings in energy curtailment from renewable sources quoted in the application. A detailed explanation of the figures would be beneficial. (The clarification response provided by NGET warrants further discussion regarding the relationship between the maximum infeed tolerance and the size of the constraint on non-synchronous generation that results. The example given indicates that up to 19 TWh per annum, or, over the timescale of the example figures presented in the clarification process, some 60% of the total non-synchronous generation output could be constrained for inertial reasons). |
| | Answer (a.iii).1: In our response to question 24, we provided a snapshot of the model which is developed to calculate the total energy curtailment from renewable sources, as well as a summary of the calculations behind the tool. The model, and the result which we obtained, were validated against the historical incidents. For example, the method we use to calculate the total system inertia, and decide on how much the df/dt would have been for an infeed loss, was validated against the historical incidents. Similarly, the volume of response required are validated based on the frequency deviations observed on the system, and what our model (in addition to the spreadsheet, we simulate the response in PowerFactory) shows. The only variable is the list of generators running in the future, which to overcome this uncertainty, we use Future Energy Scenarios which are widely consulted with the industry.<br><br>The calculations are based on the ranking orders of particular year, and using the dispatch model (which the tool uses) to determine the level of system inertia, maximum loss tolerance, and the size of the maximum loss for each hour.<br><br>The relationship between the level of non-synchronous generation which will be curtailed and the maximum loss tolerance is as follows:<br><br>1. When the non-synchronous generation technologies are generating, they are displacing conventional generation technologies which provide inertia. This is true in all cases as |

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| | within the ranking order, the generation units which go down in the merit (because of increasing the penetration of non-synchronous generation technologies) are the units which have inertia.<br><br>2. The model determines how much synchronous generation (out of the units which were displaced) needs to be brought up in order to provide sufficient level of inertia to cater for the largest loss. This assumes no increase in the volume of response, and sets a limit on the largest loss tolerance. It effectively determines system's non-synchronous generation limit assuming the volume of response will remain the same. Hence, as noted in the question, this will result is significant curtailment of volume of non-synchronous generation because of inertia reasons.<br><br>An increase in the volume of response will avoid curtailment of on-synchronous generation and this represents an increase in the speed of response, and in a based on the current system capability will result in significant increase in the volume of response as calculated in Appendix 6. |
| | Conclusion (a.iii).1: This is a reasonable explanation of the process that has been adopted in performing the calculations.<br><br>It is reasonable for these calculations to have been performed assuming no increase in the level of response, as this effectively represents a base case for comparison with the provision of enhanced services from the EFCC method. |
| | Challenge (a.iii).2: NGET should explain whether any analysis has been undertaken of the trade-offs on carbon benefits between obtaining frequency control services from renewable generation and the reduced output that is required to hold fast reserve capability on this generation. |
| | Answer (a.iii).2: Yes, we have conducted number of analysis in this area, focusing mainly on the response capability of technologies such as wind and the impact on their output if they are to provide fast response. This was done as part of Grid Code Working Group GC0022:<br><br>http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/Grid-code/Modifications/GC0022/<br><br>In EFCC, there are number of technologies which are envisaged to |

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| | provide fast response:<br><br>• Wind<br><br>• Demand Side Response<br><br>• Solar PV and Storage<br><br>• HVDC (not trialled but the service will be applicable)<br><br>As well as trialling fast start-up of a synchronous power plant (this is mainly to compensate potential shortfall in power delivery capability of fast acting resources).<br><br>Other than Wind, the other technologies do not require to operate at reduced output to provide response. Solar PV and Storage are combined to deliver the overall response from a non-constrained source. In case of DSR, there is no reduced output. And in case of HVDC, the initial response envisaged will be provided from the DC charging within IGBTs, and DC cable (in case of VSC technology and if already operating at rated output without overloading capability), or by change in power set-point: http://digital-library.theiet.org/content/conferences/10.1049/cp.2012.1968?crawler=true<br><br>In case of CSC-HVDC, by change in power set-point the necessary response can be provided.<br><br>In case of wind technology, we held number of discussions with wind turbine manufacturers and were made aware of different approaches to provide fast response; particularly in case of Full Converter WTGs which allows the power output to remain at the rated output and provide the fast response without de-loading by using the stored energy. There are of course considerations such as how long the response can sustain for etc. which are the exact purpose of performing trial on site. |
| | Conclusion (a.iii).2: The value of site trials is fully recognised as a means of showing the extent to which fast response can be sustained by the different generation sources, and the role of CCGT in underpinning the shorter-term delivery from other sources is understood.<br><br>It is not clear how the trial including the combination of battery storage and solar PV is being configured, however in bilateral discussions NGET have confirmed that operation of the solar PV in |

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| | constrained mode is anticipated as part of the trials. The point was made that reserves are inevitably going to be required from renewable sources moving forwards, with a corresponding need to constrain some of these in order to hold reserve capability.<br><br>This aligns with the justification for using the Belectric patent, which relates to the technical operation of solar PV at part load. |
| Sub-criterion (a.iv)- Robustness of financial benefits | Challenge (a.iv).1: A major issue concerns the robustness of the financial benefits quoted and the assumption that almost all the services procured from conventional sources can be replaced through the EFCC project. Reassurance is required that the scale of the rollout required to deliver the financial benefits quoted, including achieving the participation of sufficient generation and consumers in the provision of reserves, is possible. |
| | Answer (a.iv).1: The financial benefits, are calculated based on the validated models which as described in response to (a.iii).1 were subject to thorough validation. The cost figures, are again "conservative" figures, as described in the main bid document. We have consulted these figures with industry, as well as our approach to calculate the constraints requirements caused because of low system inertia, and RoCoF issue as part of the joint Grid Code and Distribution Code Working Group on Frequency Changes during Large Disturbances and their effect on the total system: http://www2.nationalgrid.com/UK/Industry-information/Electricity-codes/Grid-code/Modifications/GC0035/<br><br>The roll out of the EFCC will take place following the trials which enable all service providers to participate in the new balancing service market. From the feedbacks we have received as part of our regular discussions with the service providers we are confident that the new balancing service will be attractive to those parties; given the specifications of the service will be made based on the learning of the EFCC. |
| | Conclusion (a.iv).1: Whilst the high profile of rate of change of frequency (RoCoF) in ongoing industry discussions is noted, the information provided above does not address the issue of the quantity of services needed from other providers and their likely availability. This will be highly dependent on the market model for fast frequency response services being developed satisfactorily at the end of the project.<br><br>There is significant uncertainty as to the level of definition of the new balancing service product that will be achieved in the course of the |

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| | project. It appears that considerable additional work will be required beyond the end of this project to develop the new product to a level whereby it can be introduced technically and commercially into the electricity market. |
| | Challenge (a.iv).2: The costs of providing fast reserves from the EFCC method once this has been rolled out GB-wide require more clarification, because it is not evident that allowance for payments to service providers have been included in the project Cost-Benefit Analysis. It is also unclear as to why the £9.6M project cost is replicated each year in the cost-benefit analysis for the project. The clarification responses supplied by NGET are insufficiently clear in these areas. |
| | Answer (a.iv).2: We recognise we have incorrectly subtracted the £9.6m to the assumed cost every year, the £9.6m which is a one off cost should not have been repeated. We will update the tables in our final submission.<br><br>The cost of response in 2013/14 is the cost of providing the total volume of response (which is not fast). The EFCC will avoid an increase in this cost, and the energy delivered by EFCC in the first few seconds following the loss of a generation or demand, will offset some of the requirements for "slow" primary/high response.<br><br>As a result, the offset payment in primary/high response which is achieved inherently by EFCC can be used to compensate for the service provided by the EFCC (to fast response providers).<br><br>The purpose of WP3 within EFCC is to define the optimum balance between the response delivered by EFCC, and normal Primary/High service, and optimise the cost, and volume to ensure maximum value for money in frequency control services. |
| | Conclusion (a.iv).2: The issue regarding the treatment of the £9.6m is addressed adequately, however the assumption that there will be an exact offset between the reduction in primary/high speed response that is required from other sources and the amount of money made available to pay for EFCC providers appears not to have been justified by even high level analysis. It may be concluded therefore that the costs of procuring the new fast frequency response service from the range of providers proposed is largely unknown, and inadequate consideration appears to have been given to this issue. |

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| Sub-criterion (a.v)- Capacity released and how quickly (if applicable) | No challenge presented |
| Sub-criterion (a.vi)- Replication | Challenge (a.vi).1: The future replicability of the solution will be highly dependent on the successful introduction of a new commercial mechanism to enable the participation of renewable generation in the balancing mechanism. The extent to which roll-out of a new commercial process will be feasible at the end of the EFCC project should be clarified, and the further steps and dependencies for successful implementation of the commercial mechanism should be detailed. |
| | Answer (a.vi).1: The EFCC enables creation of the new balancing service which incentivises more optimised frequency control and particularly fast response. This is the end product which EFCC will deliver, and therefore all work packages and activities are defined in order to achieve the end goal which is a new balancing service.<br><br>The key dependency of successful development of a new balancing service which does provide right level of incentive and capability to achieve an optimised frequency control is "understanding the capability of different service providers to provide response in proportion to rate of change". This will provide the portfolio of services which can be made available to the grid at different timescales, and the value of each service. The new balancing service will be rolled out and made available to all service providers based on the specification of performance requirement which is dependent on EFCC's learning. |
| | Conclusion (a.vi).1: There appears to be no clear process defined by which the balancing service that is to be defined in the project will be rolled out as part of business as usual. From detailed questioning it appears that significant work will be required beyond the end of the project before a new fast response product can be introduced into the balancing mechanism. |

### 2.3 Criterion (b): Provides value for money to electricity transmission Customers

2.3.1 Key Statements

*Proportion of benefits attributable to transmission system (as opposed to elsewhere on the supply chain).*

NGET states that the project is targeted at improving the electricity network, and that consequently the main bulk of the potential benefits of the project will accrue to the electricity transmission network and NGET's customers.

Cost savings will flow through to customers via reductions in the Balancing Services Use of System (BSUoS) charge, which are levied on generators and suppliers, as NGET's customers. Frequency control costs are cited as one of the key contributors to BSUoS charges, and EFCC will therefore reduce the costs of this component of consumers' bills.

*How learning relates to the transmission system*

NGET makes a broad claim that the learning experienced during the project will "greatly outweigh the cost". This has subsequently been clarified, as follows:

- Learning is relevant to Transmission Owners (TOs) and Distribution Network Operators (DNOs) as well as the System Operator (NETSO), because the stability of the whole system is dependent on the stability of frequency.
- TOs will benefit from enhanced system monitoring algorithms that form part of EFCC, and the additional information provided about the behaviour of users connected to their systems. They will also gain from the facilitation of connection of non-synchronous generation offered by EFCC.
- Offshore transmission owners (OFTOs) will benefit because increasing volumes of offshore wind will be able to connect to the main GB network. EFCC will enable this, whilst also providing mechanisms for offshore links to contribute to grid services.
- EFCC will provide DNOs with greater insight into the capabilities of distributed generation to contribute to system frequency control. It will also provide better understanding of the interactions between NETSO and DNOs that are required to manage system frequency.

*Approach to ensuring best value for money in delivering projects*

NGET states that delivery of the project at a competitive cost is a priority consideration, and that the company's procurement and finance departments have been engaged to ensure that best practice is followed in procurement processes.

The recruitment of partners was achieved through a competitive process of inviting and evaluating expressions of interest that began in September 2013.

NGET has confirmed that none of the project partners were involved in the initial formulation of the project or the request for expressions of interest itself.

2.3.2 Challenges and Potential Shortfalls

| **Criterion (b): Provides value for money to electricity transmission Customers;** | |
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| Sub-criterion (b.i)- Proportion of benefits attributable to transmission system (as opposed to elsewhere on supply chain) | No challenge presented |
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| Sub-criterion (b.ii)- How learning relates to the transmission system | No challenge presented |
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| Sub-criterion (b.iii)- Approach to ensuring best value for money in delivering projects<br>` | Challenge (b.iii).1: A significant level of contingency (20%) is applied to the time inputs allowed for the project partners. This should be explained, as tighter project planning should enable this to be reduced. (In the clarification process, NGET has indicated that this may be reviewed in the final proposal submission, and evidence of this review should be provided.) |
| | Answer (b.iii).1: EFCC is a complex project involving a number of partners. We are currently working with our partners to develop a more detailed project plan, broken down into subtasks. This plan will enhance our understanding of the partners' contribution to this project and their risks associated with this project and enable a full review of contingency costs.<br><br>We have already identified potential reductions and are confident that where contingency costs are 20% they will be brought down significantly. Revised costs will be provided as part of the final submission. |

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| | Conclusion (b.iii).1: The revised project programme shows more detailed consideration of individual tasks. This could therefore lead to greater certainty about the required activities and hence a reduction in the levels of contingencies, although this is subject to confirmation in NGET's final submission. |
| | Challenge (b.iii).2: The hardware costs associated with battery storage and reactive power provision within the Belectric costs require further exploration, as at a combined total of £[redacted]k they represent a significant proportion of the capital costs of the project. The contribution of these technologies to the overall project objectives should be further justified, and confirmation should be provided that this cost covers the 2 x 1 MW battery installations referred to in the clarification process. In addition, NGET should discuss the extent to which engaging with other storage projects, such as the LCNF-funded Smarter Network Storage project, has been considered. |
| | Answer (b.iii).2: The battery storage is a central part of the fast services which EFCC will trial it. It will provide insight into real and physical possibilities of rapid frequency control and high ramp rate response. Previous studies and practical experience (for example with the 17MW-BEWAG-battery in Germany) show, that this is a key to lowering total response capacity and coping with higher volatility in the network. A battery represents an ideal add on to a system which requires a fast response, and sustaining the response, since it covers the response while the power plants are still ramping up.<br><br>A battery is very suitable for that, since it features medium investment costs, low operational costs for primary response and a high degree on local deployability. To validate this approach it is certainly necessary to deploy units on a pilot scale to provide learning about their practical applicability and to develop suitable payment schemes in order to encourage the development of a battery based primary response market, which – on the other hand – provides the best value for money for the customer.<br><br>In order for further economise on project costs it is required to use the BELECTRIC EBU 1000 on two different sites (Rainbows Solar Farm, in Gloucestershire and Redruth Solar Farm, in Cornwall). The battery unit is realised as a 40" container in order to make it movable. Additional costs for the two sites do only apply as connection costs which are being further evaluated (hence the reason for slight provision of contingency cost). So it can be stated, that the mentioned £[redacted]k |

cover the cost of one battery unit along with the two inverters (active + reactive power). With this cost figure the trials will be done on two different sites, each of them providing 1 MW of power.

We have received further breakdown of connection cost for the 2nd site. We have factored that into our cost spreadsheet which will be provided as part of submission.

With regard to the use of existing storage facilities on the system, we reviewed all battery storage installations in GB (as per attached paper "State of Charge of GB"). The locations, and the capacity of the existing installations were seen as not suitable for the purpose of this trial for the following reasons:

- The size of the available installations were either small, or the available sizes were required on regular basis for capacity purposes. The solution was to use the electrical installations and add extra battery storage which was even more expensive.
- [redacted].
- The battery storage units were not coupled with any particular onsite generators unlike what EFCC is providing.

State_of_Charge_of_GB.pdf

Conclusion (b.iii).2: From this response, it appears that there is one battery installation included that will be used at two sites; there is also however an implication that additional costs are going to be involved in the second site that have yet to be considered.

Further consideration is required of the possibilities of testing other existing battery installations for the provision of fast reserves, since the necessity for coupling these with generation sources as a prime requirement for successful tests seems marginal. A significant element of the learning that is likely to be delivered from the inclusion of battery storage technology in the project relates to the speed of response of the batteries themselves, for which the size of the installation should not be critical.

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| | Challenge (b.iii).3: The costs for Flexitricity include £[redacted]k as a "Payment to users", and costs for Centrica include £[redacted]k for "Lost output during testing". The build-up and justification for these payments in the project costs requires clear explanation, particularly as Centrica is making only a [redacted]% contribution to the project as a proportion of its costs. |
| | Answer (b.iii).3: Demand-side response will be sourced from industrial and commercial electricity customers for the purposes of the project. Such organisations are not parties to the project and receive no direct benefit from participation. The project carries risks for participants in that the EFCC approach might not prove effective or viable for long-term roll-out. Participants whose core business is other than in the technical approaches under test therefore have no motivation for participation. For this reason, payments are required to secure their engagement in the project.<br><br>We have assumed that payments will average £[redacted] per site in most cases, up to £[redacted] per site in particularly complex cases. This figure reflects Flexitricity's experience in customer recruitment for similar projects such as Low Carbon London, Capacity To Customers, FALCON and the Customer Led Network Revolution, all of which took place under the Low Carbon Networks Fund.<br><br>This should provide access to around 12 sites, which we expect to be sufficient to allow us to meet the objectives of the project.<br><br>The £[redacted]k for lost output during testing can be explained as follows. Windfarms are built and operated in order to receive ROCs and LECs. ROCs equate to approximately 43 £/MWh and LECs approximately 5.50 £/MWh. Thus any windfarm is incentivised to be available to generate as much as possible. As Lincs is an offshore windfarm it receives 2 ROCs per MWh and Lynn & Inner Dowsing windfarms each receive 1.5 ROCs per MWh. These latter two are also offshore but are subject to a different ROC regime owing to their build dates.<br><br>All windfarms submit negative bid prices into the BM to reflect the lost revenue from reducing output, as well as factoring in some form of risk element to reflect further losses that would be incurred in the event of a failure to return to service fully following some bid activity. [redacted]. The resultant bid prices for Centrica Energy's windfarms are broadly in line with others in the industry, taking due account of whether they |

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| | are subject to 1, 1.5 or 2 ROCs.<br><br>The figure of £[redacted]k was derived using an estimate of the reduction in output required to facilitate testing. Without detailed knowledge of the exact testing required it is difficult to calculate the lost output The lost output we are referring to is a steady state reduction in output to a given load prior to frequency injection (or RoCoF injection) tests. Transient reductions in output as a result of the frequency (or RoCoF) injections are not a significant concern. Depending on the nature of the tests the lost output during the test could be much lower.<br><br>It should be noted that corresponding figure for Centrica Energy's thermal assets was considerably lower at £[redacted]k. This reflects the fact that thermal plants are not in receipt of ROCs and LECs and also that for a thermal plant, a reduction in output leads to a saving in fuel. |
| | Conclusion (b.iii).3: NGET presented calculations suggesting that Centrica would need to be compensated for lost revenues over a 10 day trial period. Calculations have been presented to demonstrate that compensation would be paid at the rate of £[redacted] per MWh for wind generation and £[redacted] per MWh for lost profit on thermal generation. These figures are not unreasonable, however it will be important to ensure that the testing is carefully planned and that adequate results can be obtained in the proposed 10 day test period. |
| | Challenge (b.iii).4: The equipment costs for Alstom include costs of Phasor Measurement Units. Reference is made to links between the EFCC project and the VISOR project that was funded in Year 1 of the electricity NIC. NGET should explain the extent to which additional equipment is needed over and above that already being funded through the VISOR project and confirm that maximum use is being made of the work already being undertaken in VISOR. Any cost savings achievable through greater integration with the VISOR project should be highlighted. |
| | Answer (b.iii).4: Through VISOR, Wide Area Monitoring (WAMS) data from all of the Transmission Owners in GB will be centralised and new measurement points enabled. In the EFCC project, there are two requirements for phasor measurements in the GB system: |

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| | 1. Fast detection, location and proportionate response requirement calculation<br>2. Capturing the detailed time-response of the frequency service provision, required for designing the aggregation of service provision<br><br>The VISOR project will provide the monitoring data for the first requirement, while the additional equipment is required for the second requirement, specifically to capture the sub-second synchronised detail of the response to the triggering events.<br><br>The work undertaken in VISOR will be fully used in the EFCC project. Specifically:<br><br>• The work on measurement infrastructure will be used to provide the input data<br>• The available event detection approach, enhanced through VISOR to provide more accurate location and event impact will provide experience for the EFCC algorithm<br>• The archive of measured data, including event capture, will provide key data for trialling the MCS approach.<br>Since VISOR is for monitoring, not control, there are aspects in the implementation in the GB grid that are specific to EFCC. In particular, latency is much more important in EFCC than in VISOR. The EFCC project will extend the statistical assessment of latency of the VISOR measurement infrastructure, and also define the timing requirements throughout the system. The EFCC demonstration projects in Manchester University and Strathclyde PNDC will demonstrate the capabilities of technology for fast round-trip control.<br><br>We have reviewed VISOR's key deliverables and we will closely explore the potential for cost savings which may include:<br><br>• Infrastructure enhancements to enable a central source of data<br>    o Communications links between ScottishPower, SHE and National Grid<br>    o Phasor Data Concentrator in SHE<br>    o Phasor Data Hub in National Grid<br>• Phasor Data Hub archiving of system events |

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| | • Study and algorithm development for monitoring and control purposes has overlap.<br>From the VISOR project, £925k was allocated for the following components in deployment of a GB-wide WAMS:<br><br>- Server Costs<br>- Two communication links from national grid to ScottishPower and SHE<br>- Software<br>- Support Services<br>The infrastructure provided through VISOR will be used in the EFCC project, reducing the cost and improving the outcomes of the EFCC project, and thus maximising the use of the investment.<br><br>Without VISOR, significantly more effort would be required to manage data from the different GB organisations, and there would be certain limitations on the MCS that could be demonstrated in a real-time environment. The project costings assume that VISOR infrastructure and outcomes are used. |
| | Conclusion (b.iii).4: There is an inconsistency here between the statements that potential cost savings from VISOR will be examined and that costings assume VISOR infrastructure and outcomes are used. However, NGET have subsequently confirmed in bilateral discussions that the hardware from VISOR will be fully utilised to the extent possible and that this is taken into account in the project costings. |
| | Challenge (b.iii).5: Confirmation should be provided that project scope and costs cover all the communications systems required to enable the system demonstrations involving customer installations to proceed. |
| | Answer (b.iii).5: We have discussed this with all project partner, and can confirm the cost figures enable the trials including any requirements for installations at service providers' end. |
| | Conclusion (b.iii).5: It is understood in the light of this response that the project budget includes the costs of communications equipment required to enable the MCS to communicate with the customer installations that are to be tested in the trials. |

## 2.4 Criterion (c): Generates knowledge that can be shared amongst all relevant Network Licensees

### 2.4.1 Key Statements

*Potential for new/incremental learning to be generated by the project*

Specific learning that it is stated will flow from the project includes:

- the development of an innovative control and monitoring system that can detect and differentiate between system disturbances and frequency events;
- understanding the frequency response capabilities of a range of different technologies;
- demonstrating the potential for coordinating the response of different technologies in order to optimise overall response;
- identifying the best infrastructure for centralised and decentralised frequency control; and
- integrating the technical learning from the project into economic decision making on the transmission system.

*Applicability of Learning to Other Network Licensees*

As noted under Criterion (a), NGET has cited a broad range of learning that is relevant to transmission and distribution licensees. This is centred on the provision of information about the performance of different sources of generation on the networks and the contribution that it makes to the control of frequency.

*Proposed IP management and any deviations from default IP principles*

It is stated that EFCC will comply fully with the default IPR arrangements, and that NGET's project partners have been made aware of these arrangements and have agreed to comply with them.

It is not anticipated that any of the developments carried out under the EFCC project will fall outside the default IPR arrangements. [redacted]. This would however be in compliance with the arrangements for "Foreground IPR" as covered in Section 9 of the NIC governance document, and would lead to the availability for purchase of a product on fair and reasonable terms.

*Credibility of proposed methodology for capturing learning from the trial and plans for disseminating*

A range of knowledge dissemination approaches is proposed, including:

- forums that NGET currently hosts, including the Grid Code Working Group, the Operational Forum and the Security and Quality of Supply Standard Group. These have been involved in gathering ideas on system needs;
- a new working group to be formed, with widespread industry representation from manufacturers, academics, suppliers, aggregators, generators and network licensees, to monitor the project and to provide challenge and review;
- the development of an on-line portal (the "EFCC e-hub") to enable data sharing and the promulgation of the results of the trials;
- significant input by the academic partners into the dissemination of information, through a range of papers, newsletter and conference presentations;
- "hands-on" involvement of interested parties and stakeholders in laboratory demonstrations and simulations, at Manchester and Strathclyde Universities.

2.4.2 Challenges and Potential Shortfalls

| **Criterion (c): Generates knowledge that can be shared amongst all relevant Network Licensee;** | |
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| Sub-criterion (c.i)- Potential for new/incremental learning to be generated by the project | No challenge presented. |
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| Sub-criterion (c.ii)- Applicability of learning to other Network Licensees | No challenge presented. |
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| Sub-criterion (c.iii)- Proposed IP management and any deviations from default IP principles | Challenge (c.iii).1: It is noted in the project costs that allowance is made for payments to Flexitricity and Belectric for the use of IP that has already been developed. The patents relate to the aggregation of DSR and the part-load operation of solar PV generation. The fees have been calculated based on percentages of the total work package costs in which the patents are deployed. Further justification is required of the |

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| | £[redacted]k for the use of the Flexitricity patent and its treatment as the sole funding contribution to the project from Flexitricity. |
| | Answer (c.iii).1: [redacted]. It will be used during WP2.3 for frequency response. Patent [redacted] describe the usage of [redacted]. It will also be used for the in WP 2.3. It will enable a wide range of experiments and provide comprehensive learning.<br><br>Patent [redacted] describes some of the features of the deployed [redacted] which will be used in WP 2.4. Patent [redacted] describes [redacted]. This is one of the configurations, which will be evaluated in the early phase of WP 2.4 along with the communication with the NETSO (see also [redacted]).<br><br>All mentioned patents are filed under a company named Adensis GmbH which is the patent holding organization of Belectric. Belectric has the right to use of all of these patents.<br><br>Each of the 2 main patents for WP 2.3 has been valuated with [redacted]% of the overall cost of the working package. This was divided by 2 for the 2 first years of project realization (when appropriate trials are scheduled to take place) and offered as yearly contributions. For WP 2.4 each of the 3 patents has been valuated with [redacted]% of overall cost only, since the patents cover a smaller part of the working package than they do in WP 2.3. The resulting value has been broken down to the total 3 years of project realization.<br><br>For Flexitricity UK patent number [redacted] covers the material concerned. There are two main areas in which this patent supports the project.<br><br>Firstly, the use of [redacted] permits DSR to provide all three identified forms of EFCC more efficiently and more cost-effectively. It would be possible to include demand response in EFCC without this contingency, but this would carry a greater risk of the TSO purchasing too much or too little EFCC, which would either raise costs to the consumer or lessen security of supply. This patent is therefore capable of increasing the value which the consumer gains by sourcing EFCC from DSR.<br><br>Secondly, variable speed drives on industrial and commercial electricity-consuming equipment configured to respond to variations in frequency is likely to be an essential component of one particular strand of demand response EFCC, namely, |

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| | simulated inertia through variable speed control. This is likely to be the major source of simulated inertia in the project and, if successful, in a full-scale deployment.<br><br>As DSR is a very new area, the value of patents is difficult to determine in an objective way. One method of estimating this value is by extrapolating from similar activities where we already have commercial activity. Considering the gross annual value of our longest-standing frequency-response customer, if our patents were to *increase* participation in DSR EFCC by two to three similar sites over the course of one year, we arrive at the valuation stated. Other methods produce higher valuations. For example, companies with intellectual property in similar areas (which, for the avoidance of doubt, does not impinge on Flexitricity's ability to exploit its patents) have valuations of the order of £10m. In this context, we believe that the value of these patents to the project and the EFCC concept is not overstated in the application. |
| | Conclusion (c.iii).1: The statement that two or three additional sites being encouraged to participate in DSR being equivalent to the £[redacted]k value attached to the Flexitricity patent is not unreasonable. In addition, applying effectively a licence fee approach that is based on [redacted]% to [redacted]% of the value of the work packages in which the Belectric patent is being applied is a reasonable basis for attributing a value to the patent. NGET has explained the rationale for not contacting demand side participants at this stage, due to the uncertainties surrounding what they would be asked to participate in, which is accepted. |
| Sub-criterion (c.iv)- Credibility of proposed methodology for capturing learning from the trial and plans for disseminating | Challenge (c.iv).1: The proposed approaches to knowledge dissemination are satisfactory, if somewhat generic in nature. The proposed hands-on access to facilities at Manchester and Strathclyde is innovative, but more evidence is required of the way that access to these facilities would arranged and that allowance has been made for the costs of running stakeholder events involving hands-on demonstrations within the project budget. |
| | Answer (c.iv).1: The approaches to knowledge dissemination are listed below:<br><br>1. Co-ordinated Internal Knowledge Dissemination Organisation of Industrial Stakeholders Workshops; Exchange of key skills relevant for understanding of frequency control in future networks; Cross- |

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| | fertilisation of industrial and academic views; Use of The Manchester RTDS and Strathclyde PNDC as a support and showcase for the co-ordinated Internal Knowledge Dissemination<br><br>2. Co-ordinated External Knowledge Dissemination<br>Collaboration with European, USA (EPRI), Chinese (China EPRI), Indian (IITs, Transmission Network Owners - TNOs), Brazilian… industry and academic partners; Participation in IEEE and Cigre Working Groups and Task Forces; Academic conference and journal papers, website and project newsletters, events at PNDC/Strathclyde/Manchester.<br><br>3. Contributing to creation of new policies and standards<br>Grid Code updates/modifications; Existing PMU/Data Concentrator IEEE Standards updates;<br><br>4. Knowledge Dissemination through Public Domain Engagements<br>EFCC Website; Project progress reports; Annual Conferences; News Letter (how frequently it will be published, will be decided by the Project Management; for example quarterly Newsletters).<br><br>5. Specialised Training Courses<br>At Manchester and Strathclyde, using the HiL facilities. The *Specialized Training Courses* will be focused on the challenges directly related to the EFCC project. Both academic partners are considering the costs of Specialized Courses as our in-kind contribution to the project. The scale of this contribution might exceed the existing total in-kind contribution (£[redacted]k for Manchester and Strathclyde together), but academic partners are happy with this considering that this kind of courses might significantly contribute the overall understanding of the "frequency and inertia challenge" and will on the top of that offer opportunities for exchanging knowledge on a more spontaneous and interactive manner.<br><br>6. Final results shared<br><br>Project Close Down Report and Evaluation Workshop (3 days); A joint academic paper in e.g. *IEEE Power and Energy Magazine*, addressing the key project |

deliverables.

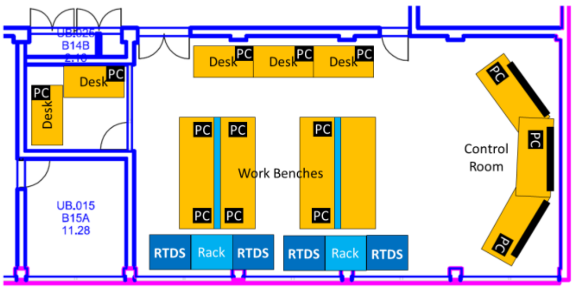
More details about the facilities at Manchester and Strathclyde are given below.

**a) The Manchester Real Time Digital Simulator (RTDS)**

In Figure below The Manchester Real Time Digital Simulator (RTDS) is presented. It is now temporary located in the National Grid Power Systems Research Centre. The Centre is located at The university of Manchester in Ferranti Building. The RTDS was commissioned in July 2014 and at the moment the University is finding the optimal solution where it will be located.

The Manchester RTDS

In Figure below the layout of the laboratory in which the Manchester RTDS will be located is given. It is envisaged that the simulator will be located in Ferranti Building, Room B14 and that the facilities will be ready for use in this form from April 2015. However, independent on these plans, all 6 RTDS racks are right now fully operational and in use in 3 separate research projects.



Layout of the Manchester RTDS

Next to the Manchester RTDS, the laboratory for HiL has been recently extended with 5 brand new Omicron V/I CMS 156 amplifiers (the total value £100k). By combining the RTDS and amplifiers, a various type of HiL testing using real devices is possible.

**b) PNDC in Glasgow**

The PNDC is completely geared towards demonstration and showcase activities. A spacious control room with panoramic views of the compound is available. This includes a large wall-mounted display unit which can be used for presentations/videos, or more importantly as a real-time slave display mirroring the status on the main network-control computer. There are also several subsidiary flexible indoor laboratories of various sizes, for the use of visiting companies and institutions to site their experimental/instrumentation equipment in, or provide "tradeshow" style demonstrations. A large indoor LV test-bay provides multiple connection points for devices such as an EFCC-equipped unit to be demonstrated under controlled conditions. Safe and escorted access to laboratories and the outdoor compound can be arranged and the facilities for witnessing tests and demonstration are an integral element of the design of the centre. The centre can easily cater for 60 external visitors without requiring the finances to hire external meeting venues, and several large industry-facing events have already been held. A selection of photographs of the facility are included below.

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| | <br>Power Network Demonstration Centre in Glasgow |
| | Conclusion (c.iv).1: This appears to indicate that any cost over-runs arising from the hands-on demonstrations will be borne by the universities. It would be desirable if the universities could confirm this in writing. |

## 2.5 Criterion (d): Is innovative (ie not business as usual) and has an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness

### 2.5.1 Key Statements

*Justification that the project is truly innovative*

NGET identifies a series of risks inherent in trialling new services, as well as highlighting specific aspects of the proposed project that are innovative.

Key elements of innovation claimed include:

- Development of a control system that enables:
    - a world-first approach to using non-conventional sources of frequency response services;
    - real-time triggering of fast-response services using wide area signals;
    - co-ordination of diverse range of frequency response capabilities and providers;

- monitoring and instruction across the transmission and distribution networks.

- The incorporation of demand side response into fast response provision.

- Modifications to CCGT control systems to respond to machine speed as a direct measure of the rate of change of frequency.

- Novel operation of PV plant taking account of:

  - the need to operate below the maximum power point in order to provide capacity for reserves;

  - provision of reactive power to support the ramping of real power output.

- Investigation of the capabilities of a battery in providing frequency response, including the development of innovative command and control schemes, and the technical and financial evaluation of the battery contribution.

- Assessment of the capability of wind farms to contribute to response provision.

- Coordination of response from a range of resources, optimised locally and nationally, and controlled via a Wide Area Control System.

- Application of Hardware in the Loop Testing and the novel testing/demonstration facilities at the Power Networks Demonstration Centre (PNDC) in Glasgow.

- A “hands-on” approach to knowledge dissemination proposed by the academic partners.

*Justification that NIC funding is required and credibility of claims*

The justification that NIC funding is required is based on the fact that EFCC is presenting an innovative approach to dealing with frequency control on a system where maintaining stable system operation is paramount.

NGET points out that there is no provision for trialling new services as part of Business-as-usual, especially where new infrastructure needs to be built for demonstration purposes. The new Monitoring and Control System that is proposed will work alongside existing Phasor Measurement Units, and seek to instruct frequency response services from a range of generation resources and the demand side.

*Identification of project specific risks*

A range of technical, operational, commercial and regulatory risks is identified which would prevent the project being introduced as "business as usual". These include:

- the need to develop and test communications, measurement quality, control systems and response capability from a range of response providers;
- the risks to security of the grid system if the scheme were introduced without proving its performance;
- the need to develop and test new commercial arrangements to support the participation of the demand side and renewable generators in the provision of fast response services; and
- the required investigation of the regulatory implications of introducing technology such as EFCC and its impact on system planning and operating standards.

### 2.5.2 Challenges and Potential Shortfalls

| **Criterion (d): Is innovative (ie not business as usual) and has an unproven business case where the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness;** | |
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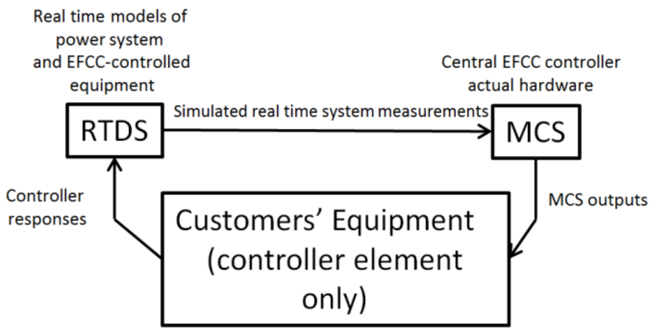
| Sub-criterion (d.i)- Justification that the project is truly innovative | Challenge (d.i).1: It is clear that many areas of the project are innovative in their coverage, particularly the broad vision of obtaining fast response service from diverse sources connected at the transmission and distribution levels, taking account of the locational variation rates of change of frequency following incidents. The argument for NIC funding hinges on the risks of introducing EFCC as business as usual without extensive proof and testing, and yet clearly actual customer sites and generation installations are going to be tested within the project. A fuller explanation is required of the way that the closed-loop demonstrations involving customer equipment will be performed and the extent to which these will impact on the normal operation of the system and the customer installations. Confirmation is also required that the NETSO is fully committed to enabling these tests to take place. |
| | Answer (d.i).1: The simulation and validation process is planned to be undertaken in the following three major stages:<br><br>1. Hardware in the Loop (HiL) using the Manchester |

RTDS
2. Using the PNDC at Strathclyde and
3. Trialling at selected sites

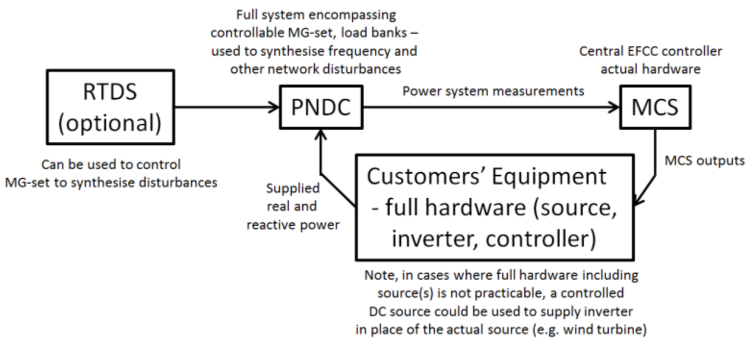
In Figure below a block diagram of the "Manchester RTDS" HiL testing is presented.




Block diagram of Manchester RTDS HiL testing arrangement

The closed-loop demonstrations involving customer equipment simulated in the simulator will be performed in a flexible manner, what is offered by the RTDS simulator. The extent to which customer equipment will impact on the normal operation of the system and the customer installations will be assessed using the simulator.

In Figure below, a block diagram of the PNDC HiL testing is presented.




PNDC HiL testing arrangement

Demonstrations involving customer equipment will be also assessed using the Strathclyde PNDC. The testing may be done in one of 2 modes. Firstly, in an open-loop mode, pre-programmed frequency and/or voltage deviation profiles can

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| | be generated using the on-site 1MVA synchronous set, driven using the variable-speed drive. The response of an EFCC-equipped device to the scenarios can be analysed to assess the effectiveness and stability/robustness of the EFCC scheme. Such an open-loop mode is useful since it allows an identical scenario/test to be repeated many times, allowing a consistency in assessment.<br><br>A more advanced mode is to close the loop and include a real-time RTDS model of the upstream power network. A disturbance from nominal can then be introduced either in the RTDS simulation, or in the hardware network (e.g. a load step). The response of the EFCC can again be analysed to assess the effectiveness and stability/robustness of the EFCC scheme. The results of such closed-loop tests are often more interesting than results from open-loop pre-programmed scenarios, but can be harder to interpret due to the closed-loop nature and the multiple interactions between control systems within the DUT (Device Under Test) and the RTDS simulation (governors, AVRs etc).<br><br>The most sensible approach is to use a combination of open-loop and closed-loop test scenarios to provide a full and comprehensive analyses of any proposed DUT.  The PNDC is a valuable resource for providing realistic testing of selected EFCC functions, with *no* impact on customers as it is a test facility buffered via a motor-generator set) from the utility system.<br><br>The uniqueness of the centre is that it is real, flexible, can be used to execute system transients (voltage, frequency, current, power quality) and can be used to integrate equipment in “full hardware in the loop modes”. It uses the “PowerOn Fusion” power network management system, has extensive measurement and monitoring capabilities, and can interface with RTDS and other external simulation packages. The office consists of 900m$^2$ of floor space, along with an extensive indoor LV lab containing connection points, and of course the outdoor compound. The network can be operated in grid-connected mode or as an islanded system supplied via a motor-generator (MG) set with a variable speed drive. The MG set has a continuous power rating of 1 MVA and its synchronous machine is rated at 5 MVA. Operating in decoupled mode presents opportunities to vary system voltage and frequency – which can be used to test the frequency response of devices and systems. There are also facilities to introduce power quality disturbances, phase imbalance and to apply resistive |

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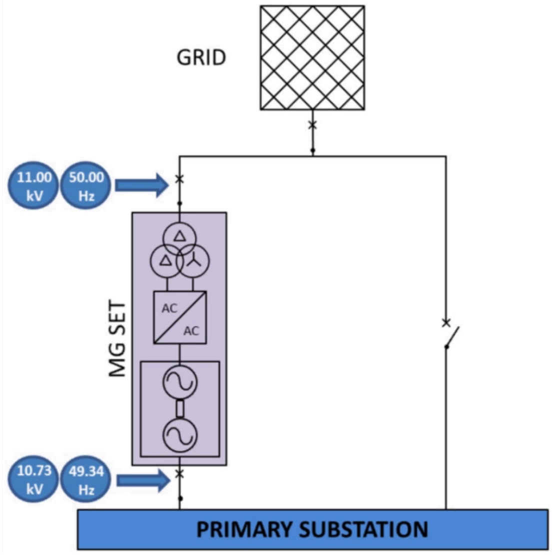
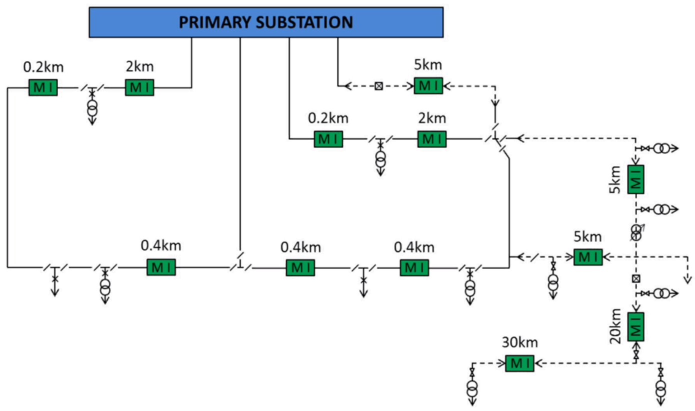
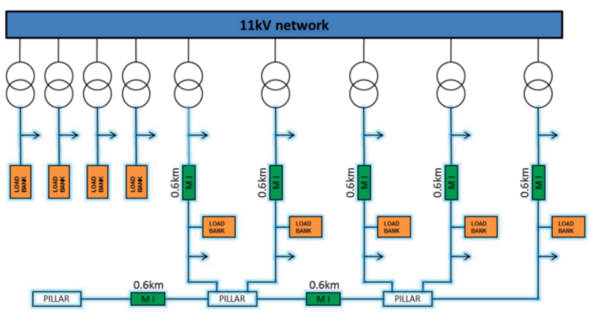
| | short circuits, which can be used to test fault detection, protection discrimination and stability, and the ride-through capability of network-connected devices (e.g. distributed energy resources, storage, etc.). This will also be useful in testing the performance and stability of the enhanced frequency response systems under other non-frequency-impacting system transients and local event. This allows more extensive and faster test programmes for new technologies to be conducted.<br><br>The centre has interconnected 11 kV and 400 V networks and can be configured as an urban, hybrid (urban/rural) and/or rural network, with a capability of emulating 11 kV distribution lines of up to 60 km in length. The centre consists of an outdoor compound containing overhead and underground 11 kV equipment, comprising pole- and ground-mounted transformers and substations with associated protection and control equipment. There are test points at which devices to be demonstrated or tested can be connected directly to the 11kV network. An LV network is also available, supplied via several transformers from the 11 kV system. The LV network can be loaded using a variety of programmable load banks, and contains points for connections of devices under test.<br><br>Secondary injection facilities, an industry-standard supervisory control and data acquisition (SCADA) system with control room, a real time power system simulator, a large indoor LV laboratory and several other laboratories and offices, along with comprehensive high-fidelity monitoring and data historian facilities, complement the primary system hardware available at the centre.<br><br>The MG set can be controlled locally, from the control room via the SCADA system or using the centre's real time digital simulator (RTDS). The PNDC can be operated in grid-connected mode (the right hand connection on the figure) or in decoupled mode via the MG set (left hand connection) when frequency transients and other disturbances are being applied. |




Grid-connected/decoupled modes so that frequency and other disturbances may be applied




11kV system (with impedances that can emulate up to 60 km line lengths)




LV system with impedances and load banks

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| | The submission of the EFCC has been agreed at National Grid's System Operator Executive Committee. We can confirm that all proposed activities within EFCC, including the necessary trials can take place given the full agreement from NETSO has already been obtained. |
| | Conclusion (d.i).1: This appears to indicate that tests of actual customer installations are not incorporated into the Hardware in the Loop (HiL) testing functions. This suggests that considerable attention will need to be paid in the project to the successful integration of the results of the HiL tests and the site tests of customers' installations. It is understood that the response of individual customers' installations will be modelled within the PNDC as part of the work of the University of Strathclyde, but that this will be the limit of the integrated testing of the solution. This represents an area of considerable uncertainty in the project, and has yet to be satisfactorily developed or described. |
| | Challenge (d.i).2: Given that high renewable penetration is a feature of the power systems in a number of countries internationally, notably Ireland and Denmark, the extent to which research has been carried out into the methods used elsewhere to control system frequency in the presence of eroded inertia should be explored, and the way that this learning is reflected in the specification of the project should be explained. Specific reference should be made to the level of engagement that has been undertaken with EirGrid and the DS3 project in Ireland. |
| | Answer (d.i).2: We acknowledge that the main bid document has not made reference to the previous engagements which we had with other TSOs and this will be done in the final submission.<br><br>As discussed in the Bilateral Meeting on 21st August; we have engaged with number of different stakeholders on various aspects of dealing with increasing the penetration of renewables. This has been done at number of different forums such as ENTSO-e working groups, in our bilateral meetings which we regularly organise to share the best practise, and particularly as part of Grid Code Review Panel.<br><br>With regard to EFCC, and linkage with DS3 programme, we have both reviewed their work in detail (this was done very recently and as part of developing National Grid's System |

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| | Operability Framework), and also met with the team who worked on the DS3 programme at the different stages of development of the EFCC and discussed the EFCC work packages in detail (last meeting was held in May 2014 when we discussed the final scope of work).<br><br>This allowed us to shape the EFCC's objectives particularly around:<br><br>• Initiation approach to frequency response and challenges with instruction of fast response => The reason that EFCC proposes response in proportion to df/dt and NOT absolute frequency<br><br>• Challenges faced with regard to provision of response from non-synchronous generation<br><br>• Cost associated with not being able to provide a service similar to EFCC. This helped in validation of our forecast costs which our CBA is based on.<br><br>The issues around operation of wind power plant in a system with a very low short circuit level were also explored with Energinet (Danish TSO). The frequency control in Denmark is not as challenging as synchronous areas such as GB or Ireland given the connectivity of the Scandinavian system with ENTSO-e and sharing the inertia. |
| | Conclusion (d.i).2: It appears that some interaction with Ireland and Denmark has taken place, though it is unfortunate that this was not referred to in the earlier submission or in the bilateral meeting, where it appeared that no such discussions had happened. More detailed reference to the learning from DS3 could nevertheless be expected. |
| | Challenge (d.i).3: The extent to which learning from other LCNF and/or NIC projects has been taken account of in the formulation of this project should be identified. |
| | Answer (d.i).3: We have made reference to number of other NIA/NIC/IFI and LCNF projects in the bid document (Appendix 9). We have evaluated the relevance of all previous projects funded via these funding mechanisms, as well as other sources with EFCC, both from the <u>learning prospective</u> and <u>use of infrastructure</u> etc. |

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| | The EFCC therefore does not repeat the previous work, and builds up on the work already done. For example, we will make use of the models developed for simulation of the effect of DSR (and funded via a previous NIA). These activities bring significant savings on both cost and time for EFCC. |
| | Conclusion (d.i).3: Reference has been made to a list of other projects, but there is no indication of how the learning from these is being utilised in the EFCC project or how relevant it is. |
| Sub-criterion (d.ii)- Justification that NIC funding is required and credibility of claims | Challenge (d.ii).1: The project is innovative in a wide range of areas, and a concern relates to the very broad scope of the project. Aspects such as proving the fast response providing capability of a grid connected battery are significant areas of cost for the project and could potentially direct resources away from proving the more fundamental concept of distributed fast response provision from the demand side and from renewable generators. Furthermore, the justification for work on obtaining fast response from CCGT as a fossil-fuelled generation source is questionable. The relevance of these aspects of the project should be explained more clearly. |
| | Answer (d.ii).1:<br><br>The main reason for trialling a wide range of technologies is to ensure the future EFCC balancing service does not exclude a particular service provider who can provide the service required at lower cost. In defining the work packages which ultimately lead to development of a new balancing service, we reviewed the work done by other TSOs. <u>In many cases, the shortfall in effectiveness of the service was because of specification of the service based on limited type of technologies</u>. We therefore strongly believe the comprehensive range of technologies selected for the purpose of trial in EFCC allows us to develop a new service which will be attractive to many service providers. This will result in increase in competition, and therefore reduced price for the consumer.<br><br>With regard to trial on CCGT, it is an important aspect of the work because of potential inability to sustain the response over a long period of time reported by many technologies (such as wind, and DSR). For example, we know wind turbines may be able to provide a very fast response, and sustain for a few seconds. This may solve the initial primary/high response challenge but in a situation when many windfarms all provide |

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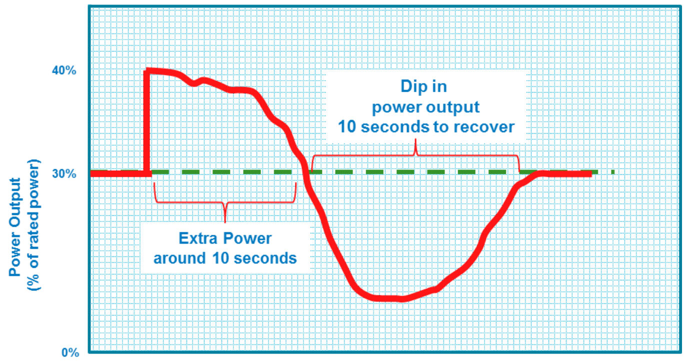
<td>a response following an incident, but then their output drops, this may result in significant power deficit in the grid:




It is therefore essential to evaluate the capability of technologies which can be brought to service with a shorter lead time, and particularly start up/ramp up after operating at low load condition (this is not similar to synchronous compensator).</td>
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<td>Conclusion (d.ii).1: The objective of achieving breadth in the range of options considered is understood, and the justification for including CCGT is clear from this response.</td>
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<td>Sub-criterion (d.iii)-<br>Identification of project specific risks (including commercial, technical, operational or regulatory risks)</td>
<td>Challenge (d.iii).1: An appropriate range of risks is identified as part of the project justification, however there is a concern as to how many of these will be addressed adequately in the course of the project, because of the diverse range of technologies and the technical and commercial problems that it is seeking to address. NGET should be asked to explain:

- how fully the risks are mitigated through the implementation of the project,
- how confident they are that potential contribution of alternative forms of fast reserve provision will be tested to the point of acceptance onto the system without further technical issues having to be overcome, and
- whether the commercial arrangements will have been proved to the point of straightforward implementation as part of the GB balancing mechanism by the end of the project.</td>
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| | Answer (d.iii).1: We can confirm that the structure of the project and the workstreams is designed to manage risk adequately.<br><br><u>Risks will be addressed adequately</u><br><br>We recognise that the diverse range of technologies involved in EFCC presents a number of risks. These risks have been thoroughly considered. Our Risk Register outlines the actions we will take to mitigate these risks. Risks will continue to be identified and mitigated throughout the project implementation.<br><br>We have brought in project partners at the proposal stage and they have assisted us in identifying all risks and formulating appropriate mitigation actions.<br><br>We have a number of systems, processes and resources in place to address project risks. Our PMO will provide support and a dedicated project manager will be appointed. Regular meetings will take place at different levels of seniority and an EFCC Steering Committee will be formed. NGET management are fully supportive of EFCC and resources are in place to ensure successful delivery.<br><br>NGET will draw on its considerable experience of implementing large-scale projects. We are confident that risks have been fully mitigated.<br><br><u>Alternative forms of response will be tested</u><br><br>The monitoring and control system will be tested at four different locations, with each providing a different level of testing. This will ensure the platform is sufficiently tested before deployment in the network.<br><br>The potential alternative forms of response will be thoroughly trialled. This will be achieved through close co-operation between NGET and our partners. Our academic partners, the universities of Manchester and Strathclyde have expertise in testing and will provide state-of-the-art facilities, such as the Manchester Real Time Digital Simulator (RTDS) and the Power Networks Demonstration Centre (PNDC). Both of these will be used for hardware-in-the-loop testing. Detailed system studies and modelling will be carried out, and validation and testing will go beyond current requirements (in terms of |

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| | RoCoF, etc.) to give full confidence. Given the critical role these response providers will play in managing frequency, NGET will ensure that they have been fully tested and verified ahead of deployment.<br><br>Commercial arrangements will be proved<br><br>NGET has allocated sufficient time and resources in order to ensure commercial arrangements are in place and ready to be implemented by project close in Q1 2018. Investigations and analysis will begin early (Q3 2015) and run in parallel with the technical testing.<br><br>We have significant experience in developing commercial arrangements and we will combine this with the expertise of our partners, with particular support from our academic partners. Through ongoing dissemination activities we will share progress and information with the wider industry. This will enable potential EFCC providers (beyond the project partners) to take part in the commercial arrangements. |
| | Conclusion (d.iii).1: Whilst National Grid has experience in implementing large scale engineering projects, it is less clear that this is being fully brought to bear in the development of this complex innovation project. This is reflected in the lack of integration in the structuring of the project as a whole.<br><br>There is insufficient clarity in the descriptions of the project tests to enable a clear understanding of the relationship between tests at the academic facilities and tests of customer installations, and the way in which the project outputs will lead to the clear definition of a new frequency response product is unclear. |

## 2.6 Criterion (e): Involvement of other partners and external funding

### 2.6.1 Key Statements

Appropriateness of collaborators (including experience, expertise and robustness of commitments)

NGET describes the steps that have been taken to promote the EFCC project and to gain the interest of potential project partners and supporters. A range of external stakeholders were engaged with in the process of formulating the project, and formal expressions of interest were sought from parties interested in participating in the project. The project partners identified are as follows:

- Alstom – Technology Provider – responsible for developing the Monitoring and Control System (MCS). Contributing £[redacted]k to the project through reduced labour rates and equipment.

- Belectric – Solar PC and Storage developer – providing response capability from PV power plants and storage facilities. Contributing £[redacted]k to the project through reduced labour rates and the use of patents.

- Centrica – Large scale generation (CCGT) and wind generation – providing response capability from CCGT power plants and wind generation. Contributing £[redacted]k to the project through reduced labour rates.

- Flexitricity – demand side response. Flexitricity will recruit industrial and commercial customers as required and interface its customer control system to the MCS. Contributing £[redacted]k to the project from making its patents available for use.

- The University of Manchester – Real Time Digital Simulation (RTDS) system. Contributing in-kind support of £[redacted]k from access to the RTDS, laboratory space and inputs from technical staff.

- The University of Strathclyde – Power Networks Demonstration Centre (PNDC). Contributing in-kind support of £[redacted]k from access to their RTDS system, the PNDC and associated technical staff.

### 2.6.2 Challenges and Potential Shortfalls

| **Criterion (e): Involvement of other partners and external funding;** | |
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| Sub-criterion (e.i)- Appropriateness of collaborators (including experience, expertise and robustness of commitments) | Challenge (e.i).1: Whilst the range of partners appears appropriate, the letters of support from other than the academic participants do not specify the level of in-kind support that each partner will provide to the project. Further written assurances from the project partners regarding the level of their financial contributions. |
| | Answer (e.i).1: We have received additional confirmation from all partners in written format including their level of |

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| | contribution. We will attach the letters in the final submission. |
| | Conclusion (e.i).1: This response will be sufficient, if the letters referred to demonstrate adequate commitment. |
| | Challenge (e.i).2: The inclusion of two universities in the project requires justification, and with a more detailed explanation of the nature of the work that each will be undertaking and where there are similarities, differences and interfaces between the activities for which each is responsible. |
| | Answer (e.i).2: The Universities of Manchester and Strathclyde have proposed a partnership that will assist the National Grid-led EFCC consortium in researching, developing, demonstrating and testing technologies that are capable of providing rapid power modulation to address frequency containment and system stability under future low-inertia scenarios.<br><br>The partnership offers a complementary suite of expertise and facilities, which will be combined to deliver a very effective contribution. The partners have an excellent working relationship and are presently collaborating on the EPSRC-funded £1m UK/India "Advanced Communication and Control for the Prevention of Blackouts (ACCEPT)" project, investigating prediction of instability and protection techniques to mitigate the risks of blackouts in future power systems, which is relevant to the work proposed here.<br><br>Manchester, led by Professor Vladimir Terzija, Dr Viktor Levi and Dr Robin Preece, offers experience and expertise in the field of system inertia monitoring and control, wide area situational awareness, dynamic frequency security assessment, system transient studies, protection and control and in the use of PMU data to facilitate such functions, as well as practical testing of intelligent Electronic Devices. In July 2014, the UK's largest Hardware in the Loop (HiL) testing facilities (The Manchester RTDS) was commissioned in the National Grid Power System Research Centre at Manchester. This will create an opportunity to perform best-in-class, high-fidelity simulations and validation of the expected project outcomes. Strathclyde, led by Dr Campbell Booth, Dr Andrew Roscoe and Dr Adam Dyśko, offers: experience and expertise in the provision of advanced control algorithms that can provide fast-acting "inertial" responses from inverter-interfaced sources, loads and energy storage; experience of researching and |

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| | developing novel frequency-based protection methods; and, crucially, access to a major new facility, the Power Networks Demonstration Centre (PNDC), which will be invaluable in demonstrating the project outcomes.<br><br>Both Strathclyde and Manchester have conducted extensive research in these areas and both partners bring new algorithms and solutions for fast frequency response, some of which have already been demonstrated, and some of which are more "blue sky".<br><br>The academics from Manchester have a long track record in voltage analysis and control research. Current research capability includes:<br><br>- Extensive modelling and simulation experience of networks (frequency response, control and stability).<br><br>- Analysis of power system transients, both fast – EMTP and slow – electromechanical.<br><br>- Mixed ac-dc networks modelling (CSC and VSC HVDC transmission systems).<br><br>- Modelling and simulation of renewable energy resources including off-shore wind-farms.<br><br>- Modelling and simulation of demand; real-time estimation of load model parameters.<br><br>- Design of controllers for voltage/frequency regulation.<br><br>- Extensive experience with a wide-range of modelling packages (DIgSILENT PowerFactory; EMTDC/PSCAD; EMTP-RV; PSS/E, IPSA+) and methodologies (RTDS experience for control and protection studies).<br><br>- Extensive experience with other hardware in the loop systems: National instruments, LabView, Omicron, small scale Real Time Digital Simulator (RTDS)<br><br>- Wide-ranging internationally recognised expertise across the whole field of relevant power engineering<br><br>Manchester is currently undertaking a number of projects |

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| | related to frequency control (a selection of £1m+ projects):<br><br>1. EPSRC "Advanced Communication and Control for the Prevention of Blackouts (ACCEPT)" – 2014-17 £1million project investigating the modelling, operation and design of future Smart Grid technologies which will support robust power system control and prevention of large scale system blackouts – consortium of 3 universities from the UK and 3 universities from India<br><br>2. SUPERGEN 1 "Renewal Core - FlexNet: Renewal of the Supergen consortium on Future Network Technologies" – 10/2007-03/2012; EPSRC £6.8M project No EP/E04011X/1.<br><br>3. EPSRC "Supergen HubNet" – 2011-2016. A project of £4.7million delivered by 8 Universities to stimulate and support underpinning research in energy networks using the established expertise of the core HubNet members and provide research leadership in the field particularly through the publication of position papers and workshops .<br><br>4. EPSRC "Grand Challenge 'Top and Tail'" – A project of £3.8million delivered by 8 Universities studying the technology requirements to enable the transition to a low carbon future<br><br>5. EPSRC "Grand Challenge Autonomic Power Systems" – A project of £3.5 million delivered by 7 Universities focusing on the electricity network in 2050.<br><br>6. Network Innovation Competition "VISOR" project – a project of £7.46million in which The University of Manchester is supporting the work on developing and validating advanced visualisation tools of future GB system and mechanisms for monitoring Sub-Synchronous Oscillations in the system<br><br>In the past, the researchers from Manchester have published several publications, which as such determine the directions of the development of new Smart Grid applications for transmission grids. Some of them are listed below:<br><br>1. P.Wall, V.Terzija, "Simultaneous Estimation of the Time of Disturbance and Inertia in Power Systems", IEEE Trans. on Power Delivery, VOL. ??, Issue ??, pp ?-?, Year, DOI ? Accepted for publication on 09/02/2014 |

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| | 2. P.Regulski, D.S.Vilchis-Rodriguez, S.Djurović, V.Terzija, "Estimation of Composite Load Model Parameters using an Improved Particle Swarm Optimization Method", IEEE Trans. on Power Delivery, VOL. ??, Issue ??, pp ?-?, Year, DOI ? Accepted for publication on 14/01/2014<br><br>3. D.Cai, P.Regulski, M.Osborne, V.Terzija, "Wide Area Inter-area Oscillation Monitoring Using Fast Nonlinear Estimation Algorithm", IEEE Trans. on Smart Grid, Volume: 4, Issue: 3, 2013, pp. 1721-1731, DOI: 10.1109/TSG.2013.2257890.<br><br>4. H.Novanda, P.Regulski, V.Stanojević, and V.Terzija, "Assessment of Frequency and Harmonic Distortions during Wind Farm Rejection Test", IEEE Trans. on Sustainable Energy, Volume: 4, Issue: 3, 2013, pp. 698-705, DOI: 10.1109/TSTE.2013.2242499<br><br>5. R.Regulski, V.Terzija, "Estimation of Frequency and Fundamental Power Components Using an Unscented Kalman Filter," Instrumentation and Measurement, IEEE Transactions on , vol. 61, no. 4, pp. 952-962, April 2012, DOI: 10.1109/TIM.2011.2179342<br><br>6. F. Gonzalez-Longatt, P. Regulski, H. Novanda, V. Terzija, "Impact of Shaft Stiffness on Inertial Response of Fixed Speed Wind Turbines", Automation of Electric Power Systems, No. 8 Vol. 36, April 2012, DOI: 10.3969/j.issn.1000-1026.2012.08.001<br><br>7. V.Terzija, G.Valverde, D.Cai, P.Regulski, V.Madani, J.Fitch, S.Skok, M.Begovic, A.Phadke, "Wide Area Monitoring, Protection and Control of Future Electric Power Networks", Proceedings of IEEE, Volume: 99, Issue: 1, pp 80-93, 2011, DOI: 10.1109/JPROC.2010.2060450.<br><br>8. Valverde, G.; Chakrabarti, S.; Kyriakides, E.; Terzija, V.; , "A Constrained Formulation for Hybrid State Estimation," Power Systems, IEEE Transactions on , vol.26, no.3, pp.1102-1109, Aug. 2011, DOI: 10.1109/TPWRS.2010.2079960.<br><br>9. V.V. Terzija, "Adaptive Underfrequency Load Shedding Based on the Magnitude of the Disturbance Estimation", IEEE Transactions on Power Systems, Vol. 21, |

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| | No. 3, August 2006, Page(s): 1260- 1266.<br><br>10. Terzija, V.V.; Koglin, H.-J.; “Adaptive underfrequency load shedding integrated with a frequency estimation numerical algorithm” Generation, Transmission and Distribution, IEE Proceedings- , Volume: 149 Issue: 6 , Nov 2002 Page(s): 713 -718<br><br>11. V.Terzija, M.Akke, "Synchronous and Asynchronous Generator Frequency and Harmonics Behavior After a Sudden Load Rejection", IEEE Transactions on Power Systems, Vol. 18, No. 2, May 2003, pp. 730-736.<br><br>12. V.Terzija, M.Djurić, B.Kovačević, "Voltage Phasor And Local System Frequency Estimation Using Newton Type Algorithm", IEEE Trans. on Power Delivery, Vol.9, No.3, July 1994, pp.1368-1374.<br><br>Strathclyde has been, and remains involved in several projects that are relevant and complementary to the proposed EFCC, including: dynamic assessment of wind generation synthetic inertia contribution to the GB power system, funded by SP/SSE; EPSRC Program Grant to investigate aspects of high penetrations of renewable energy into power systems; EU TWENTIES project – VSC modelling and novel VSC design that helps to mitigate the impact of faults, and pan-European analyses of the impact of offshore grids and interconnectors; BestPaths - an EU FP7 project that brings together an international team of TSOs, manufacturers and academic researchers to develop new technologies and innovative system integration approaches to facilitate large-scale penetration of renewable energy production into the European transmission network; algorithms for provision of synthetic inertia from HVDC links - "Inertia Emulation Control Strategy for VSC-HVDC Transmission Systems," IEEE Transactions on Power Systems, vol.28, no.2, pp.1277,1287, May 2013; “Virtual Synchronous Machine” algorithms – development of concepts for configurable "true" inertia and fault ride-through capabilities being developed within inverter controllers.<br><br>The academics from Strathclyde have also a long list of publications on the topic relevant for the EFCC project.<br><br>In the text below, an overview of the activities which will be undertaken by Manchester and Strathclyde in specific Work |

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| | Packages (WPs) is given.<br><br>Academic partners will be involved in the following WPs: 1, 3, 4, 5 and 6. In summary, Manchester has requested one RA for 3 years (RA1), one RA for 1 year (RA2) and one PhD student for 3 years. Strathclyde has requested one RA for 2 years (RA3). Both academic partners also have involved academics, as described in EFCC project proposal.<br><br>The major role of the RA1 is involvement in computer simulations based studies and HiL testing using The Manchester RTDS. The specific focus will be responses from wind farms, DSR and PV.<br><br>The major role of the RA2 is involvement in computer simulations based studies oriented to the risks and economic value of the EFCC scheme.<br><br>The major role of the Manchester PhD student is involvement in computer simulations focused on the coordinated supervisory control of the Monitoring and Control System.<br><br>The major role of the RA3 is involvement in computer simulations based studies and HiL testing using Strathclyde PNDC. The specific focus will be invertors, energy storage and RoCof issues relevant for the MCS.<br><br>In the text below, a more detailed overview of the activities of academic partners is given.<br><br>WP1: Power Factory based system studies to ensure the robustness and efficacy of the proposed Monitoring and Control Scheme - MCS;<br><br>Involvement of RA1, RA3 and a PhD student from Manchester; all researchers must understand how the MCS works.<br><br>Further details about the work to be done:<br><br>System studies of the MCS based on the use of the standard IEEE test networks; testing of both the sensitivity and stability of the MCS and its operation under various network and transient conditions.<br><br>System studies of the MCS based on the use of the GB model |

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| | suitable for the study; testing of both the sensitivity and stability of the MCS and its operation under various GB network and transient conditions<br><br>WP3: Power Factory based system studies to demonstrate the system response without/with supervisory control; Development of the actual supervisory control strategy;<br><br>Involvement of the RA1 and a PhD student from Manchester.<br><br>Further details about the work to be done:<br><br>System study demonstrating risks if co-ordination is not facilitated.<br><br>Selection of the optimal supervisory control strategy; Development of the co-ordinated supervisory control; Demonstration of the supervisory control using basic IEEE test networks.<br><br>Assessment of the robustness and efficacy of the developed supervisory control.<br><br>WP4: Validation<br><br>Involvement of all 3 RAs and the PhD student from Manchester.<br><br>Further details about the work to be done:<br><br>*Validation activities through system studies.*<br><br>*HiL Validation of the Monitoring and Control Scheme (MCS)*<br><br>Development of appropriate RSCAD models for the purpose of the RTDS-type testing; creation of a suitable network in PNDC and testing using actual system components.<br><br>Manchester RTDS HiL testing of the MCS - RSCAD model development; RTDS testing; Assessment of a range of system cases and operational conditions<br><br>Strathclyde PNDC testing of the MCS - Creation of an appropriate physical model suitable for the testing of frequency response and the proposed MCS; Assessment of realistic situations and demonstration of the capabilities of the |

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| | MCS. Testing under a variety of frequency transients and testing robustness of MCS to non-frequency transients (e.g. voltage dips, short circuit faults, etc.).<br><br>*RTDS/PNDC testing of the individual responses of various EFCC-enabled sources/loa-*<br><br>Use of the HiL and PNDC to test both the sensitivity and stability of the EFCC scheme and its operation under various transient conditions; Detailed results will be logged an compared with the outcomes of earlier system studies.<br><br>*Manchester RTDS HiL testing of the co-ordinated supervisory control*<br><br>Development of a detailed RSCAD model; RTDS HiL testing; demonstration of the capabilities and limitations of the proposed supervisory control strategy.<br><br>Strathclyde PNDC testing of the co-ordinated supervisory control - Creation of an appropriate PNDC laboratory setup; PNDC HiL testing; demonstration of the capabilities and limitations of the proposed supervisory control strategy.<br><br>WP5 – Dissemination<br><br>All members of the team of academics will be involved in this WP.<br><br>WP6 – Commercial<br><br>Involvement of the RA2 from Manchester<br><br>Involvement of the RA2 from Manchester + Partners; Manchester RA2 will be assessing the reliability of the proposed EFCC scheme, as well as the economic value of the scheme. |
| | Conclusion (e.i).2: On the evidence of this response, both universities seem to offer similar skills and experience in the analysis of the frequency response of systems.<br><br>The universities do offer complementary testing facilities in relation to real-time simulation at Manchester and the use of the PNDC at Strathclyde. Further clarification has been provided as to the split of the academic budget between the |

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| | institutions. This indicates that the University of Manchester will receive £[redacted]k and the University of Strathclyde £[redacted]k. Following clarification, the figures have been increased by a total of £[redacted]k, however doubt has been introduced regarding the level of in-kind contribution to be received from the Universities. This will require further examination in the final submission and greater comfort is still needed that there is no duplication of effort between the two university teams. |
| Sub-criterion (e.ii)- External funding (including level and security of external funding) | Challenge (e.ii).1: The relatively small contribution to the project from Centrica should explained, and the possibility of their increasing the amount of in-kind support that they are to provide should be explored. |
| | Answer (e.ii).1:<br><br>The vast majority of costs estimated by Centrica Energy are either related to the lost output from windfarms during testing or costs charged by external parties, i.e. the OEMs. Centrica applied a significant reduction to its internal charging rates for staff involved in this project and has also spent several many days on this project – no claim will be made for any time incurred so far. Centrica Energy have established the support of Alstom and, once further progressed, will leverage their relationship with Alstom and, also, Alstom's desire to be at the forefront of such developments to seek reductions in Alstom's normal rates for any work required on their part. Siemens have expressed a similar desire to be involved as our windfarm OEM and Centrica Energy will adopt a similar approach here.<br><br>Centrica's contribution is estimated at £[redacted]k. It should also be noted that Centrica Energy are committed to this project and the attendant risks it imposes upon its plants. Many generators, particularly windfarm generators, would not countenance such risk. |
| | Conclusion (e.ii).1: There is a mismatch between the statement that Centrica have applied a "significant reduction to its internal charging rates" and the contribution of £[redacted]k. It is however recognised that Centrica will have an important role in managing the inputs of the OEMs involved in the generation equipment modifications. |
| | Challenge (e.ii).2: Further documentary evidence from the non-academic project partners should be sought to confirm their acceptance of the levels of in-kind support that are |

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| | included in the project. |
| | Answer (e.ii).2: As mentioned in response to (e.i).1 we have received the modified letters of support including the level of contribution from other partners. We will include them to the final submission. |
| | Conclusion (e.ii).2: No further issues, pending sight of the letters from the academic partners. |
| Sub-criterion (e.iii)- Effectiveness of process for seeking and identifying new project partners and ideas | No challenge presented. |
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## 2.7 Criterion (f): Relevance and timing

### 2.7.1 Key Statements

*Significance of the project in overcoming current obstacles to a future low carbon economy*

The EFCC project is cited as contributing to the alleviation of operational and environmental challenges facing NGET, in summary, how to manage the GB electricity system safely, reliably and cost-effectively as increasing amounts of renewable generation are connected to the network and the system inertia decreases.

NGET explains that the project is relevant and timely because by 2018/19, under their "Gone Green" planning scenario, inertia is reduced by 37% and the time that it would take for frequency on the system to drop to 49.2 Hz on the system will be less than half the time it takes today following a major incident. The rate of change of frequency on the system is shown to double by 2023/24 under the "Slow Progression" planning scenario.

NGET also comments that the cost of providing frequency reserves is already rising, so it is timely to implement the EFCC project now, so that a functioning and diverse frequency response service market can be implemented before costs significantly escalate.

In the project Business Case it is stated that "EFCC will allow National Grid to replace a large volume of standard response with a smaller volume of rapid response".

*The significance of the project in trialling new technologies that could have a major low carbon impact*

The potential of the technologies included in the project to contribute to the connection of larger quantities of renewable generation to the system whilst maintaining adequate fast reserve provision to compensate for falling inertia is stressed throughout the application.

*The significance of the project in demonstrating new system approaches that could have widespread application*

EFCC will enable the provision of frequency response from a range of technologies. The response capabilities of these technologies are not currently being fully harnessed, and it is therefore considered vital for the system that renewables and other resources are able to contribute to system stability.

The range of technologies under consideration therefore contributes to the widespread application of the project. In addition, the development of a commercially viable balancing service will diversify the rapid frequency response market.

*The applicability of the project to future business plans, regardless of uptake of LCTs (low carbon technologies)*

The rate of change of frequency on the system is shown to double by 2023/24 even under the "Slow Progression" planning scenario. Irrespective of this, NGET states that the key areas of learning on the project are not dependent on the take up of renewable technologies, since low system inertia is already a problem.

Furthermore, there is currently no mechanism for renewable generators to contribute to the provision of frequency response on the system, and there is therefore value in exploring the potential for cost savings over the provision of response from conventional sources.

### 2.7.2 Challenges and Potential Shortfalls

| **Criterion (f): Relevance and timing;** | |
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| Sub-criterion (f.i) – **Significance of the** | Challenge (f.i)(a).1: The application contains limited information about the volumes of reserves that are required over the timescales within which system inertia is eroded. A key concern is to understand the relevance of the trial in terms of the quantity of reserves that it demonstrates can be sourced |

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| **project in**:<br><br>(a) overcoming current obstacles to a future low carbon economy | from the range of alternative providers involved. In addition, the volumes that are required to address future system requirements need clear definition in terms of MW and MWh of resource, and the confidence with which their availability can be extrapolated from the trial requires explanation. |
| | Answer (f.i)(a).1: As mentioned in response to (a.ii) the level of response required when the inertia of the response reduces will increase substantially mainly due to the fact that the response available to the system from conventional resources will have inherent delay, and the rate of change of frequency will be much higher.<br><br>• Amount of displaced holding response from conventional generation (Gone Green)=20.2TWh<br><br>• Amount of displaced holding response from conventional generation (Slow Progression)=18.5TWh<br><br>The above figures are the volumes which will NOT be required, neither from conventional generation, nor from renewable generation technologies.<br><br>The fast response provided by new technologies allow better distribution of the existing volume of response (around 13.7TWh) into a combination of EFCC services, primary and high response and therefore shall minimise the excess volume of response.<br><br>How the distribution of response may look like, and what incentives are appropriate to achieve EFCC service will be subject to the result of trial, when we will be able to specify the EFCC service based on the learning of this trial. |
| | Conclusion (f.i)(a).1: As noted in the response to Challenge (a.ii).1, it remains unclear how the figures for the volume of reserve services from non-fossil sources have been calculated. |
| (b) trialling new technologies that could have a major low carbon impact | Challenge (f.i)(b).1: The ability to assess the scale of the low carbon impact that is claimed depends on NGET demonstrating the connection between the volume of frequency response services that will be needed in the future with the availability of the resource through accessing DSR and renewable generation sources. This is an area that requires clearer explanation. |

Answer (f.i)(b).1:

There is no actual power generated by conventional generators when holding response, however the conventional plants have to operate at lower output level to hold response rather than operating at optimum output level. Reducing the loading level could lower the efficiency and increase the emissions (i.e. NOx emissions in case of CCGTs).

With regard to the availability of DSR and renewable generation sources to provide response, through our commercial balancing services, and level of installed capacity (and future installations) we are aware of the availability of these resources. It is important to establish how these resources are integrated into the balancing services and coordinated with the other service providers to optimise the frequency control capability to provide maximum benefit for the consumer.

Example: The table below shows the ramp rate required for different inertia levels.

| RoCoF (Hz/s) | Slow Progression | Gone Green | Inertia GW.s | Action Time (to reach 49.2 Hz) | Response Rate (MW/s) |
|---|---|---|---|---|---|
| 0.125** | 2013/14 | 2013/14 | 360 | 9 | 185 |
| 0.2 | 2019/20 | 2018/19 | 225 | 4 | 400 |
| 0.22 | 2022/23 | 2019/20 | 205 | 3.4 | 489 |
| 0.25 | 2023/24 | 2020/21 | 180 | 2.4 | 679 |
| 0.3 | 2024/25 | 2021/22 | 150 | 1.2 | 1148 |

If for example in 2021/22 gone green the required 1148MW/s response can only be provided from resources which have inherent delays of around 2 seconds (at least), then the level of holding response must increase so the 1148MW/s response is delivered to the grid from significantly larger volume of response held. This will increase the emissions.

The aim of EFCC is to provide the ramp rate the system requires, from resources which are capable of providing fast ramp up/down in a coordinated way and without increasing the volume of response. By doing so, this reduces the emissions.

Conclusion (f.i)(b).1: This response provides no additional information regarding the linkage between carbon savings and fast response availability. It confirms the underlying requirement for a lower volume of fast reserves compared with existing slower reserves, however there is insufficient

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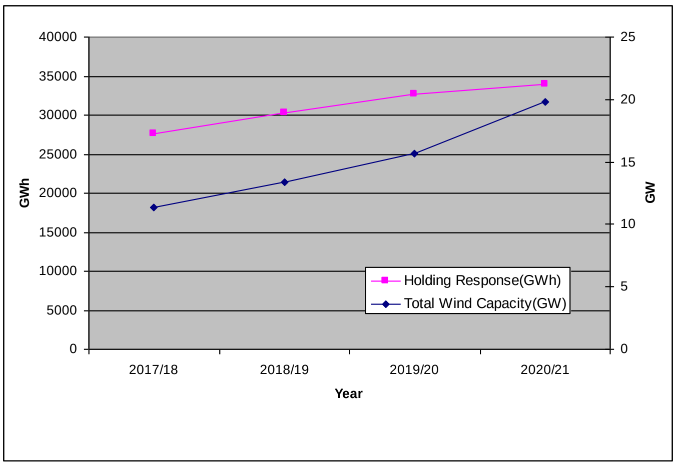
| | transparency in the calculations that link reserve requirements to carbon reduction. |
| (c) demonstrating new system approaches that could have widespread application | No challenge presented |
| | |
| | |
| Sub-criterion (f.ii)- The applicability of the project to future business plans, regardless of uptake of LCTs (Low carbon Technologies) | Challenge (f.ii).1: As part of the clarification requested in sub-criterion (f.i)(b), the sensitivity of the required volume of fast response services to the growth in renewable penetration should be demonstrated. |
| | Answer (f.ii).1: as shown in the graph below, the level of holding response has a direct relationship with the level of renewable generation penetration on the system. It is particularly important to note that the majority of the renewable generation technologies have very little or no inertia. Given the driver for increasing the volume of response is low system inertia, the increase in volume of renewables, increases the volume of response requirement.<br><br>The left Y axis shows the volume of response in GWh, and right Y axis show the level of installed capacity of Wind on the system in GW.<br><br> |
| | Conclusion (f.ii).1: This answer is helpful in demonstrating a broadly linear relationship between renewable penetration and required response volume. This confirms the importance of addressing the problem of additional fast reserve provision as inertia on the system is depleted with increasing renewable |

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| | penetration. |

## 2.8 Criterion (g): Demonstration of a robust methodology and that the project is ready to implement

### 2.8.1 Key Statements

*Feasibility of Project Proposal*

The feasibility of the project is built up from an analysis of the frequency control problem in the presence of erosion in system inertia. A new Monitoring and Control System (MCS) will be developed and used alongside existing and additional Phasor Measurement Units (PMUs) to monitor the electricity system and instruct response from a range of resources.

A range of technology-specific considerations has been factored into the development of work package 2 (WP2), including modifications to the wind generation plant with the assistance of the OEM to enable it to provide the required services.

The response from different service providers will be assessed by means of comparisons with simulated performance using flexible "hardware-in-the-loop" testing facilities and field trials at different locations.

A range of dissemination methods is proposed drawing on the different forums in which NGET works and with a key role for the academic partners.

A new balancing service product that takes account of the performance of the capabilities of the different service providers will be defined.

*All risks, including customer impact, exceeding forecast costs and missing delivery date*

A comprehensive risk register has been submitted, which details 47 specific risks across the different project workstreams.

Those with a combination of likelihood of occurrence, financial impact and reputational impact leading to the highest residual risk comprise:

- Potentially insufficient quality of technology, in terms of the monitoring and control system and the equipment installed at the response sites;
- Difficulty of upgrading technology;
- Inefficient operation of the MCS;
- Problems with the interoperability of the resources providing response services;

- Unavailability of sufficient participants for planned trials of DSR providers;
- Lack of willingness amongst industrial and commercial electricity customers to participate in trials.

*Whether items within project budget provide value for money*

The project cost breakdown is summarised in the following table (all values shown are in £000).

Whilst equipment forms a relatively small part of the overall budget, approximately half of the total equipment cost is associated with storage and reactive power equipment being supplied by Belectric. These figures appear to exclude any costs associated with modifications to generation plant that are described in the application.

A 20% contingency is allowed for on the cost of time inputs for the project partners.

| | Labour | Equipment | Contractors | IT | IPR Costs | Travel & Expenses | Payments to users | Contigency | Decommissioning | Other | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Alstom | 0.00 | 322.00 | 1068.39 | 30.00 | 0.00 | 30.00 | 0.00 | 126.42 | 0.00 | 0.00 | 1576.81 |
| Unis | 0.00 | 300.00 | 895.10 | 0.00 | 0.00 | 44.00 | 0.00 | 201.00 | 0.00 | 0.00 | 1440.10 |
| NG | 2149.99 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 | 430.00 | 0.00 | 0.00 | 2579.98 |
| Flexitricity | 0.00 | 97.00 | 461.00 | 56.00 | 285.00 | 53.00 | 650.00 | 196.40 | 24.00 | 0.00 | 1822.40 |
| Centrica | 0.00 | 0.00 | 338.00 | 0.00 | 0.00 | 0.00 | 0.00 | 45.50 | 0.00 | 340.00 | 723.50 |
| Belectric | 0.00 | 680.00 | 521.38 | 4.00 | 50.00 | 16.00 | 3.00 | 186.00 | 0.00 | 0.00 | 1460.38 |
| | 2149.99 | 1399.00 | 3283.87 | 90.00 | 335.00 | 143.00 | 653.00 | 1185.32 | 24.00 | 340.00 | 9603.18 |
| | 22% | 15% | 34% | 1% | 3% | 1% | 7% | 12% | 0% | 4% | 100% |

*Project methodology (including depth and robustness of project management plan)*

A clear governance structure is presented for the project, and it is structured into a series of clearly defined work packages, the coverage of which is as follows:

- WP1: Control System design
- WP2: Assessment of response from different providers
    - WP2.1: DSR
    - WP2.2: Large-scale generation
    - WP2.3: PV power plant
    - WP2.4: Storage
    - WP2.5: Wind
- WP3: Optimisation of response provision
- WP4: Validation of anticipated results
- WP5: Dissemination
- WP6: Commercial

A project team of named experienced specialists from each of the project partners is presented.

A high level project plan is presented, which shows the overall project timeline (running from January 2015 to March 2018). NGET states that EFCC will start in a timely manner, and will begin with initial assessments of existing equipment, with the work of the partners commencing in April 2015. There is no indication of dependencies between the workstreams in the programme, though further information has been requested in this area.

The Technology Readiness Level of the MCS is understood to be around 6-7 (Prototype or full scale technology demonstration in a working environment), as advised by Alstom.

*Appropriateness of Successful Delivery Award Criteria (SDRC)*

A series of eight SDRC are defined, which relate to the key stages of development of the project.

Three SDRC relate to project initiation; the signing of a formal Memorandum of Understanding and Agreement with the Project Partners, the successful development of the Control System and the Response Initiation Tool. These involve validation tests using the PNDC.

Two SDRC relate to analysing the response to frequency events offered by the full range of service providers and modelling to compare actual equipment test results with simulations.

The final SDRC relate to the development of a new balancing service, delivery of knowledge dissemination and successful project closure.

2.8.2 Challenges and Potential Shortfalls

| **Criterion (g): Demonstration of a robust methodology and that the project is ready to implement;** | |
|---|---|
| Sub-criterion (g.i)- Feasibility of project proposal | Challenge (g.i)1: A key issue concerns the way that the performance of the response providers will be measured and assessed. There is a lack of clarity as to the way that the results of field tests and simulations will be combined to prove the performance of the overall method. Further details are required in this area. |
| | Answer (g.i).1: as shown in below figure, the response of individual technologies trialled as part of EFCC will be recorded at different system conditions. This enables us to understand the way they behave, and their response in proportion to rate of change of frequency. This learning combined with the response capability of other technologies such as HVDC, and a range of services within the balancing services (related to frequency control) allow optimisation of the EFCC as a new balancing service.<br><br>The field test data are absolutely essential as without such trial the capability of the service providers (who are a significant proportion of potential providers of EFCC when rolled out) will not be known.<br><br>The simulation works particularly as part of WP3 enable full development of a package of services so the overall cost of frequency control is minimised. The simulations will make use of the data gathered as part of trial on site, and a realistic optimisation will be carried out which is based on real system tests. |

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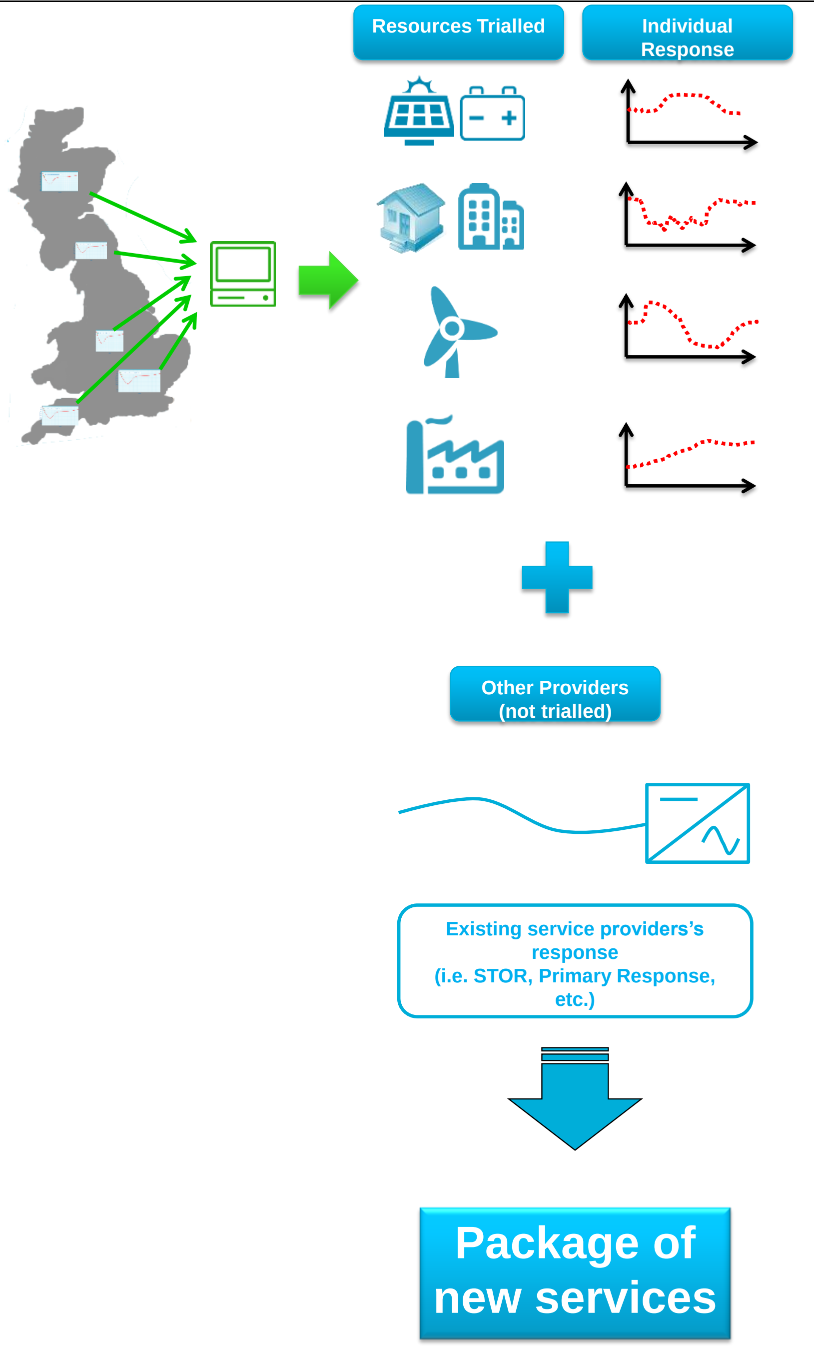
| |  |
| | Conclusion (g.i).1: This response does not provide the sort of detailed explanation of how the workstream findings will be integrated that is needed to give confidence in the overall "end-to-end" viability of the project. This issue was pursued further in the second bilateral meeting, and insufficient |

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| | additional comfort was provided that the integration of the different components of the project has been fully considered. |
| | Challenge (g.i).2: Integration of the different workstreams to deliver a successful overall outcome is likely to be a significant challenge with this project. NGET should define the possible variations on the outcomes of the project that are foreseeable and the extent to which these would deliver learning in different areas. |
| | Answer (g.i).2: The work packages are all defined with a clear overall objective; "to develop new services which enable participation of new service providers to control the system frequency in the most economic and efficient way".<br><br>There will be learning as part of all work packages; technical and commercial.<br><br>Technical: |

| Innovative Area | Learning |
|---|---|
| Ability to detect a frequency disturbance by measuring the rate of change of frequency at regional level and distinguish between disturbance or frequency event at very fast timescale (below 200ms) | The factors influencing regional RoCoF, the measures to avoid the system split, the realistic timescale which reliable regional RoCoF need to be measured |
| Ability to identify the size of loss, the geographical location of loss, and the calculation of required response in proportion to rate of change of frequency at regional level | The impact of loss of generation/demand at regional/overall system, detection methods, and decision making on type of response needed |
| Demonstration of ability to instruct very fast response at regional level based on the method described above, and ensure the overall level of response delivered at the national level reduces the cost | Capability of the different instruction algorithms to achieve fast response, reliability/redundancy of the service required |
| Demonstration of coordinated response between different service providers, and appropriateness of different control philosophies (df/dt vs absolute frequency) | How exactly fast response can minimise the volume of response. Whether the requirement should be continuous or triggered only when system inertia is low |
| Demonstration of capability of | Capability of a wide range of |

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| different service providers to respond to the frequency response instruction as per the method described above | technologies to provide rapid response, and in proportion to rate of change, their sustain time, overall impact |

Commercial:

| Innovative Area | Learning |
|---|---|
| Development of performance requirement for development of an Enhanced Frequency Control Capability as a new balancing service | How a fast frequency control service is defined using the trials from a wide range of technologies, how the service should attract sufficient range of providers to be successful. |
| Development of new service which incentivises the fast response to optimise the overall volume of response required | Service definition to offset substantial volume of inefficient response, the ways the financial incentive should be made available, duration of the service, and procurement windows required. |
| Development of response scheduling programme to use a combination of conventional services, as well as EFCC at times envisaged each benefiting the system. | Interaction of EFCC with other services, identification of potential areas of conflict. |

As shown in above tables, there are different areas which will generate learning. Given the innovative nature of this project, there is always a possibility that the overall result is different than what it was initially assumed. If for example, we identify that delivery of rapid response within 500ms is not feasible on certain technologies, it will then be possible to specify the EFCC service in such a way that more diverse range of participants can participate in the new balancing service.

Conclusion (g.i).2: Clearly there is incremental learning that will be gained from each of the areas of activity defined in the project; the key issue of whether the different aspects are adequately integrated, however, and whether the full value of the project can therefore be extracted, remains an area of concern.

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| Sub-criterion (g.ii)- All risks, including customer impact, exceeding forecast | Challenge (g.ii).1: There appears to be significant project risk relating to the involvement of industrial and commercial customers in trials. NGET should explain more clearly the strategy for ensuring their participation, and how the project |

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| costs and missing delivery date | will be impacted if insufficient participation is obtained. |
| | Answer (g.ii).1: The level of participation of technologies such as solar PV and storage, Wind, and CCGT is not affected as we have confirmation from the service providers of these technologies as project partner.<br><br>The risk of insufficient participation from industrial and commercial sites is always significant in innovative DSR projects. It has been one of the major risk items in Flexitricity's entire business plan since the company was founded in 2004. Despite this, Flexitricity has developed the largest DSR resource in the UK.<br><br>In projects such as this there is increased risk due to the time-limited nature of the project: companies have less incentive to become involved if there is no certainty of long-term revenue. This is partially mitigated by National Grid's clear elucidation of the immediacy of the problem, and will be further mitigated through the dissemination aspects of the project, as we show industrial and commercial energy users that system inertia is as attractive a commercial opportunity as it is a real and growing problem.<br><br>However, we cannot rely on these measures to deliver real megawatts into the project. Instead, our mitigation is as follows:<br><br>1. We will seek "early adopters" in each of the three EFCC technology areas, sourcing these largely from the existing Flexitricity customer base. Many of Flexitricity's customers already have substantial geographical coverage. RBS, Tesco, The Co-Operative Group and Iceland have extensive national coverage. Norish operates a chain of cold stores from Aberdeen to Kent. Yorkshire Water and Sutton and East Surrey Water have obvious geographical diversity. Horticultural sites from Yorkshire to the Isle of Wight also participate. Within these, RoCoF is available from datacentres and HVAC. Simulated inertia is available from HVAC, refrigeration and a wide range of pumping systems. Multi-unit CHP installations at horticultural sites can provide real inertia, along with a variety of landfill gas and small hydro operators with which Flexitricity is already in discussion. |

2. We have budgeted for a total incentive of £650,000 across all sites over the course of the trials. While we do not expect to be able to offer a package which is attractive to every candidate site, we expect that sufficient sites will come forward within that budget.

Conclusion (g.ii).1: NGET, through Flexitricity, has clearly considered the range of organisations with significant demand availability that could participate in the project. There is therefore a reasonable likelihood of access to appropriate load to participate in the project as a whole. Answer g.(iii).1 gives more information about how the £650,000 is going to be applied to the customer base.

Challenge (g.ii).2: The ability of the MCS to deliver the functionality required to control the different resources contributing to fast response will be a critical component of this project. Further assurance is required that the range of functionality required across the different technologies that will be contributing to fast response delivery is expected to be achievable.

Answer (g.ii).2:

There is a range of frequency response capabilities across the response provider technologies. The diversity in the trials is helpful, both in terms of the design of the future frequency response service market, and in developing an aggregation approach that uses the available capacity as effectively as possible.

The table below outlines the target response times and characteristics of response that are expected to be achievable across the technologies.

| Technology | Provider | Characteristics of service |
|---|---|---|
| Storage | Belectric | Storage is controlled by power electronic controls, and can be deployed very rapidly. The response can be shaped in different ways through the control mechanism.<br><br>At least two response characteristics |

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| | | | will be tested in three different modes:<br><br>1. Maximum initial response, demonstrating the fastest possible rise, and sustained until either frequency is restored, or stored energy is used.<br>2. ROCOF/Frequency following. Trialing a response that could be locally enabled and controlled.<br>3. Setpoint following, demonstrating the capability to respond to a remote setpoint sent from the MCS. This mode could be used by MCS to sustain a frequency response.<br><br>In today's applications, full response is achieved within 0.5s, and trials of accelerating the response to a target of 0.1s will be carried out. |
| | Solar PV | Belectric | Solar PV will be used to deliver a high frequency response, reducing output. As the technology is connected via static converters, the response can be fast. As above, a response within 0.5s is expected. |
| | Windfarm | Centrica | The windfarm response will be triggered by an MCS unit, and will create a rapid initial response, which will be sustained for a period of several seconds<br><br>A target of 10% additional power, fully deployed in 0.2-0.5s from the trigger, and sustained for 5s is feasible in favourable wind conditions without reaching stall. The response can be replaced by |

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| | | | slower-acting longer-term response.<br><br>Previous work on Synthetic Inertia that could be provided by wind generation informs the expected response. |
| | Flexible CCGT | Centrica | The flexible CCGT control target is to enable a large volume of response (due to Low Part-Load operation), and to deploy substantially faster than the current 2-10s service requirements.<br><br>Clearly, the CCGT response cannot be as fast as a power electronic control, but the target response should start to deploy by 0.5s from the trigger, and provide a significant volume of response by 2-3s.<br><br>The exact capability profile of the technology will be tested as part of the EFCC project. Two control modes will be trialed:<br><br>1. A step setpoint change<br>2. A response to local Frequency/ROCOF |
| | Demand Side Management | Flexitricity | Demand Side Response is expected to be longer-term response, and not required to respond within the first second of the event. It is intended that the control should be deployed through its existing control and communication solution.<br><br>The response is beneficial if it can be deployed to replace the short- |

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| | term wind response, ie within 5s. This can be achieved through local control or wide-area, as appropriate. |
| | Conclusion (g.ii).2: The question of whether the MCS can respond in time to deliver these responses requires attention, and proving this will be an integral part of the project. This response indicates that a reasonable level of consideration has been given to the differing levels of response likely to be achievable from the different technologies. |
| | Challenge (g.ii).3: Utilising wind and solar generation, together with battery storage, to provide fast response services is a novel area of the project, however it is unclear the extent to which field trials are required to prove the performance of individual plant types, compared with the possibility of simulating responses. NGET should explain the balance between these activities. |
| | Answer (g.ii).3: In order to define a news service, it is essential to evaluate the performance of service providers and study the overall impact on the system. The data behind this can either be obtained from various sources such as OEM's specification, and performance curve submitted the service providers, or be obtained as part of a site test.<br><br>There is very limited information available regarding the performance of technologies such as DSR, or Wind when the rate of change of frequency is high, and they are expected to respond in proportion to the rate of change. The technical limitations will only be known if we do the site test. This will allow us to develop a realistic response portfolio of a wide range of service providers and optimise the EFCC service based on realistic data. |
| | Conclusion (g.ii).3: This appears to indicate that *only* the field trials can give the required certainty about fast variations in plant output. Given the high rates of change of frequency that exist in systems such as the Irish network, it should be possible to gain more information about the performance of specific generation technologies, especially wind, in high RoCoF situations. It is accepted however that the field trials have the potential to add incremental learning in this area. |
| Sub-criterion (g.iii)- Whether items | Challenge (g.iii).1: The way that the £650k allowance for "Payments to Customers" via Flexitricity has been calculated |

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| within project budget provide value for money | requires clarification and justification. |
| | Answer (g.iii).1: We have assumed that payments will average £[redacted] per site in most cases, up to £[redacted] per site in particularly complex cases. This should provide access to around 12 sites, which we expect to be sufficient to allow us to meet the objectives of the project. This figure reflects Flexitricity's experience in customer recruitment for similar projects such as Low Carbon London, Capacity To Customers, FALCON and the Customer Led Network Revolution, all of which took place under the Low Carbon Networks Fund. |
| | Conclusion (g.iii).1: This is a reasonable answer, and this level of payment could be expected to attract demand to participate, once the scope of industrial consumers' participation is confirmed. |
| | Challenge (g.iii).2: The process by which the £520k cost for the battery storage unit has been determined should be explained, i.e. whether competitive tenders have been sought or what the basis is for the budgetary cost estimate. Confirmation of the capacity of the battery storage that is being procured should also be provided. |
| | Answer (g.iii).2: The cost of the battery unit was determined by a competitive process with BELECTRIC being the company offering the best value for money for battery based solution and appropriate EFCC to NGET. The unit cost, and flexibility around the size of the storage unit was a major consideration which BELECTRIC was able to meet the expectation.<br><br>BELECTRIC uses the battery storage for their own production (EBU 1000), being optimised for the usage with standard 3-level solar inverters (featuring a nominal voltage of 1040V) for high cost effectiveness. This results in a price of £520k for one unit. This marks a very economic cost structure for EFCC. The cost is for example 25-50% lower than the cost of (the few) other batteries deployed on the German primary response market.<br><br>The battery technology itself is optimized for fast response i.e. has a well balanced relation between available power and capacity so that typical requirements of fast response operation may be covered. This is an intrinsic technological feature, which adds to the economic advantage of using a |

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| | BELECTRIC EBU 1000 for primary response.<br><br>Attached is the datasheet of the battery unit, showing capacity and power as well as the available power curve over time of delivery. Peak power of the battery unit is 1 MW for 20 minutes, 800 kW for 30 min and 500 kW for 60 min.<br><br>BEL_SKW_EBU1000_2014_0903_email.pdf |
| | Conclusion (g.iii).2: Whilst the capital cost of the battery appears reasonable for the capacity that is to be installed, the overall justification for not testing response provision from any of the existing batteries that have been installed under LCNF projects requires revisiting. Following extensive discussion of this issue in the second bilateral meeting, it is understood that NGET will review the possibility of using other battery installations in their final submission. |
| Sub-criterion (g.iv)- Project methodology (including depth and robustness of project management plan) | Challenge (g.iv).1: There is insufficient evidence in the application, including the project plan, that adequate consideration has been given to the way that the work packages interact and the interdependencies between them. Further explanation is required as to how the different components of the solution interact and which elements are critical to the delivery of the overall level of benefits claimed. |
| | Answer (g.iv).1:<br><br>The work packages contain interdependencies between subtasks and there are also interdependencies between the work packages. The work packages have been developed so that the sequential activities can be seen as subtasks. For example, WP2.1 DSR will see Flexitricity go through the stages of identifying, recruiting and preparing customers, before technical modifications are made and trials are undertaken. These steps must be completed in order. Across the project, our technology provider, Alstom, will interact closely with the response providers in order to establish connections with their system. Our academic partners will work with response providers in order to carry out testing and validation activities. The results of these tests will feed back into the project.<br><br>The latest version of the project plan (attached) should make |

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| | the linkages and the content of the work packages clearer.<br><br>A number of elements are ***critical*** to the delivery of the overall level of benefits claimed. The monitoring and control system must be successfully developed and communications with response providers tested and verified. The ability of the response technologies will be tested and this will have a significant impact on the project outcomes. |
| | Conclusion (g.iv).1: The revised project programme is largely descriptive in its coverage of individual tasks. A further iteration of the programme that clearly identifies the dependencies between specific activities will need to be developed, to demonstrate that the criticality of key tasks and their potential impact on the overall project timeline are fully understood. |
| Sub-criterion (g.v)- Appropriateness of Successful Delivery Award Criteria (SDRC) | Challenge (g.v).1: SDRC 9.1, relating to the signing of the project MOU, represents somewhat minimal progress. This should be redefined. |
| | Answer (g.v).1: This is noted and will be updated as part of final submission. We have made progress in contractual element of the project with our partners. Since the first submission in July, we have engaged with our partners and have appointed a dedicated Procurement Specialist within National Grid who is dealing with this matter.<br><br>Please note that this is an ongoing activity and the latest state of the contractual arrangement will be reported in October. |
| | Conclusion (g.v).1: This is an adequate response, pending sight of the final revised SDRC. |
| | Challenge (g.v).2: SDRC 9.6, which refers to the successful development of a New Enhanced Frequency Response Service, is insufficiently detailed and needs to be more specific about the end point for this activity. |
| | Answer (g.v).2: This is noted. We will update the SDRC9.6. |
| | Conclusion (g.v).2: This is an acceptable response, pending sight of the final revised SDRC. |

# 3 Response Summary

Following a detailed review of the proposal documents, as well as attendance at bilateral meetings and examining clarification responses, a number of challenges have been presented in this report to the Enhanced Frequency Control Capability project put forward by National Grid.

The remaining issues regarding this project concern the following points:

- the assessment of project benefits, in terms of carbon saving and financial benefits. There is insufficient visibility of the calculations and assumptions that define the quantities of fast response that are needed to compensate for the future degradation of system inertia. In addition, greater clarity is required regarding the calculation of the volumes of conventional generation that will be displaced by the proposed fast response services.

- the intended project deliverables, and particularly whether a new fast response service will have been adequately defined to the point that it can be commercially rolled out at the end of the project and what additional steps may be required for the service to be implemented successfully.

- the extent to which the integrated performance of the different elements of the project method will have been demonstrated. It is unclear how the trials of the responses of individual customers' equipment, be it generation or demand side response, will be integrated in order to demonstrate the overall effectiveness of the proposed fast response service. A clearer explanation is needed of the way that individual tests of the MCS and its interactions with specific customer installations will be combined into an assessment of the viability of the overall fast response service definition.

- project management issues concerning the extent to which the interactions between particular work packages are fully understood and their dependencies recognised. The way in which the work packages will be integrated in the project as a whole is unclear. This is particularly the case in relation to the testing that will be carried out by the universities and the trials of customers' equipment.

- the roles of the two universities, and particularly the degree of interaction that is required between them the and potential overlap that is included in their work.