Issue 06

Enhanced Frequency Control Capability (EFCC)

Progress report: July to December 2017

Contents

Executive summary

Great Britain's (GB) electricity sector is becoming increasingly decarbonised; many traditional thermal power stations have closed and will continue to close. There is also more renewable generation on the electricity network, including battery storage, solar photovoltaics (PV) and wind.

This changing energy landscape leads to potential system challenges that are explained in National Grid's System Operability Framework (SOF)*. One of these challenges is that while traditional thermal power stations provide inertia, renewable generation technologies typically do not. Inertia acts as a natural aid in maintaining system frequency. Reducing system inertia increases the risk of rapid changes in system frequency and the threat of severe faults on the electricity network.

National Grid is working with industry and academia on the Enhanced Frequency Control Capability (EFCC) project. This aims to identify innovative ways to control frequency in low inertia transmission systems. It will explore how technologies such as demand-side response (DSR), solar PV, wind and different ways of operating combined cycle gas turbines (CCGTs) can help to keep the transmission system stable in the most cost-effective and efficient way.

* https://www.nationalgrid.com/uk/publications/system-operability-framework-sof

Summary of progress: July to December 2017
During this reporting period, the focus continued to be on demonstrating the GE Grid Solutions' monitoring and control scheme and on handing it over to project partners for validation and technical field trials. Site acceptance tests were successfully completed at Flexitricity's demand-side response client site, a chemicals plant in north-east England, and at South Humber Bank CCGT Power Station.

Site acceptance tests for the National Grid demonstration will be completed during the next reporting period. This will deliver a demonstrable but secure solution that will provide useful learning for a business-as-usual approach. This also includes the potential to link up with other partner sites, which shall maximise the benefits of the National Grid demonstration. This may lead to additional requirements for communications protocols that can be used on the National Grid information networks that are consistent with both current and future operating principles, such as security.

With support from GE Grid Solutions and National Grid, commercial project partners Belectric, Centrica and Flexitricity are performing technical field trials, respectively, for solar PV, battery, CCGT and DSR fast frequency response.

The University of Manchester and the University of Strathclyde are continuing to validate the monitoring and control scheme. During the validation period, academic partners were supported by GE Grid Solutions. Queries and issues were analysed in a timely manner and updates provided when necessary. Tests performed will be documented by academic partners and made available for knowledge dissemination.

During these activities and this reporting period, it became clear that configuration settings of the monitoring and control scheme need to be defined carefully. Settings need to be representative of the GB power system as well as for the case studies adopted. GE Grid Solutions, National Grid and project partners have discussed configuration management and settings in great detail in order to establish a realistic baseline for future deployment. By aligning settings with all project stakeholders, the overall project validation exercise will be conducted in a consistent way that will represent a business-as-usual implementation more accurately.

There have also been many workshops to assess the data communications, protocols, infrastructure, data quality, system security and user access requirements needed to support the implementation of the monitoring and control scheme into business-as-usual activities.

The project team is now focused on the final phases of the project and bringing together all of our learning and experience. This will help develop a commercial framework to encourage the widest participation in a new market for fast frequency response.

Project background and business case

We need to increase our use of renewable generation in order to meet future carbon reduction targets. However, this presents a challenge because most renewable generation does not provide inertia (an object's resistance to any change in motion). A reduction in system inertia is known to increase the risk of rapid changes in system frequency and consequently the threat of severe faults on the electricity network. This means that we will need to deliver more frequency response more quickly to keep the transmission network stable.

National Grid is working with industry and academia through our EFCC project to identify innovative ways to control frequency in low inertia transmission systems. The project aims to explore how technologies such as DSR, solar PV, wind and CCGTs can help to keep the transmission system stable in the most cost-effective and efficient way.

By developing an innovative wide-area monitoring and control frequency response system (MCS), the EFCC project aims to allow newer, more sustainable energy solutions to provide more frequency response. The project will also develop and introduce commercial incentives and products designed to encourage the widest participation in a new market for fast frequency response.

The challenge of managing low system inertia is not unique to National Grid so we'll share important knowledge from the project with relevant network licensees and service providers. We'll also share the results of trials, and the solutions offered, with global Transmission System Operators (TSOs). To discover more, please visit our project website at http://www.nationalgrid.com/efcc or email us at box.EFCC@nationalgrid.com.

Project manager's report

The project received formal approval and the project direction in December 2014. This is the sixth progress report and covers the period of July to December 2017.

Major project deliverables during the reporting period include:

Site acceptance testing – the focus was on demonstrating the GE Grid Solutions' monitoring and control system and handing it over to project partners for validation and field trials. Site acceptance tests were successfully completed at a Flexitricity demand-side response customer site and at South Humber Bank CCGT. Site acceptance tests were also successfully completed at the University of Manchester, the University of Strathclyde and the solar PV plant owned and operated by Belectric in the previous reporting period. One remaining site acceptance test, for the National Grid demonstration, will happen soon.

PhasorController training – GE Grid Solutions delivered a comprehensive training course to provide project partners with sufficient knowledge of PhasorController equipment, PhasorPoint monitoring software, EFCC applications and Phasor Measurement Unit (PMU) equipment.

Project knowledge sharing and dissemination – project representatives recently attended the Low Carbon Networks and Innovation (LCNI) Conference in Telford. The project had a stand in the exhibition hall and participated in a presentation session. Both attracted a broad range of stakeholders and generated plenty of interest.

Work package 2.4: Battery storage – Network Innovation Allowance (NIA) funding has been approved to cover the costs of leasing the Belectric battery storage facility during the EFCC trials. Contractual arrangements between Belectric and National Grid have recently been concluded. It is anticipated that EFCC battery storage trials will be able to start in early 2018.

Further detail on each of these project highlights can be found later in this report.

Project steering committee

The project steering committee is responsible for:

- developing and agreeing project activities
- approving project results
- raising, testing and reducing identified risks to the project
- authorising changes to the project plan.

The project steering committee continues to hold frequent teleconference and face-to-face meetings to discuss project progress, identify and manage risks, and agree actions.

There have been no changes to the steering committee in this reporting period. However, Julian Leslie has succeeded Richard Smith as the Head of Network Capability – Electricity and therefore as the project sponsor.

Project progress against successful delivery reward criteria (SDRC) milestones

Progress against our SDRC milestones during this reporting period is shown in Table 1 below. Further details are also provided in the SDRC chapter later in this report.

Table 1
SDRC summary: July to December 2017

Description	Due Date	Status
Monitoring and control system developed successfully: control platform development: revision completed	31 July 2017	Achieved 26 July 2017
Response analysis from service providers: CCGT power stations	31 July 2017	Ongoing*1
Response analysis from service providers: windfarm	31 July 2017	Ongoing*1
Response analysis from service providers: PV power plant	31 October 2017	Ongoing*1
Response analysis from service providers: demand-side response	30 November 2017	Ongoing*1
Successful validation of response: successful delivery of representative models and validation of trial results using the models	30 November 2017	Ongoing*1
Successful development of new enhanced frequency response service as part of new balancing services	31 December 2017	Ongoing*1

*1 These activities are ongoing and have either passed the original due date or are unlikely to be completed by the original due date. However, it is anticipated that all of these activities will be finished before the project closes in March 2018. Nevertheless, the project steering committee continues to evaluate all options available including the possibility of seeking a project extension from Ofgem.

Project risks

The robust project structure and governance process make sure that any issues or changes that could affect project delivery are identified quickly and that actions are put into place to resolve them. Appendix C provides an update of the project risk register. Major risks for this reporting period can also be found later in this report.

Project knowledge sharing and dissemination

The project team will continue to:

- record and share all lessons learned throughout the lifetime of the project
- discuss and assess all learning points through ongoing reviews and project meetings
- share outcomes and breakthroughs at conferences, workshops and university demonstration events as appropriate
- upload and share reports on the project website wherever possible – however, most of the project reports are part of the intellectual property that is being developed.

Events attended and publications submitted during this reporting period by all project partners are listed in Table 2 below.

Table 2

Knowledge sharing and dissemination events: July to December 2017

Event/Publication	Date	Organisation	Contribution
Intersolar, EES Europe, Munich, Germany	June 2017	Belectric	Presentation on battery storage in Europe: technical solutions on how to improve grid infrastructure
National Grid Future Energy Scenarios (FES)	July 2017	Flexitricity	Presentation on flexibility provided by business energy users
Institution of Diesel and Gas Turbine Engineers: Emerging Opportunities	September 2017	Flexitricity	Presentation on spinning inertia provided by gas engines
IEEE PES, Innovative Smart Grid Technologies (ISGT) Conference, Torino, Italy	September 2017	University of Strathclyde	Presentation of the paper: 'application of a MW scale motor generator set to establish power hardware-in-the-loop capability'
CIGRE UK, Next Generation Network 10 Year Anniversary Event, Manchester, UK	October 2017	GE Grid Solutions University of Strathclyde	Poster presentation of the EFCC scheme and results from tests at the PNDC
Heriot-Watt University	November 2017	Flexitricity	Presentation to engineering students, including inertia and frequency response
The Energy Management Exhibition	November 2017	Flexitricity	Presentation on energy policy and its implications for demand-side flexibility, including EFCC opportunities
ADEPT Annual Conference	November 2017	Flexitricity	Presentation on the role of local authorities enabling smart systems, including EFCC capable investments
ADE Heat 2017	November 2017	Flexitricity	Presentation on flexible operating modes for CHP generators
Low Carbon Networks and Innovation (LCNI) Conference, Telford, UK	December 2017	All partners	Exhibition and presentation of the EFCC project (see next page for more information)
IET Scotland, Invited Talk, Glasgow, UK	February 2018 (synopsis submitted)	National Grid GE Grid Solutions University of Manchester University of Strathclyde	Presentation on 'application of a wide-area monitoring and control technique for fast frequency response in the GB transmission network'
IET International Conference on AC and DC Power Transmission 2018, Chengdu, China	June 2018 (abstract submitted)	University of Manchester University of Strathclyde	Presentation on fast frequency response for effective frequency control in power systems with low inertia
IEEE Power Systems Computation Conference (PSCC)	June 2018 (abstract submitted)	University of Manchester	Presentation on 'small signal based frequency response analysis for power systems' and 'trajectory sensitivity analysis of rate of change of frequency using system frequency response model'

Low Carbon Networks and Innovation (LCNI) Conference

The LCNI Conference is an opportunity to explore the key learnings from electricity and gas network innovation projects in focused presentations and workshops. According to current project timelines, this year's conference will be the last for the EFCC project team.

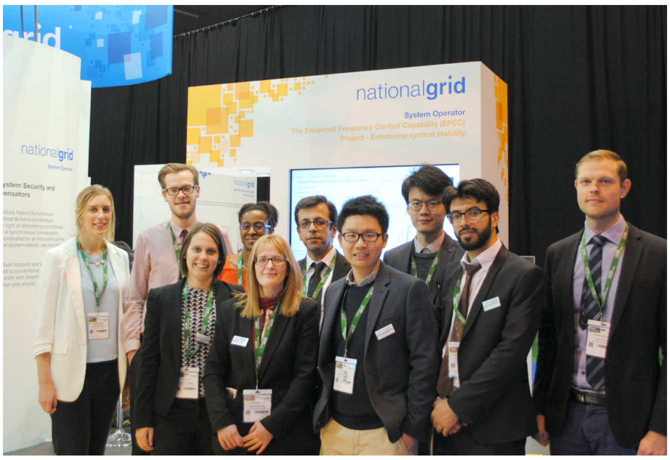
On 6 December 2017, Lilian Macleod, the EFCC Project Manager, presented EFCC in the 'Low Carbon Technology – Distributed Generation' session. The presentation covered key messages including why the project is needed, what it aims to achieve, how this is being done and what benefits the project hopes to bring to consumers. Other project partners were also available during the session to answer questions.

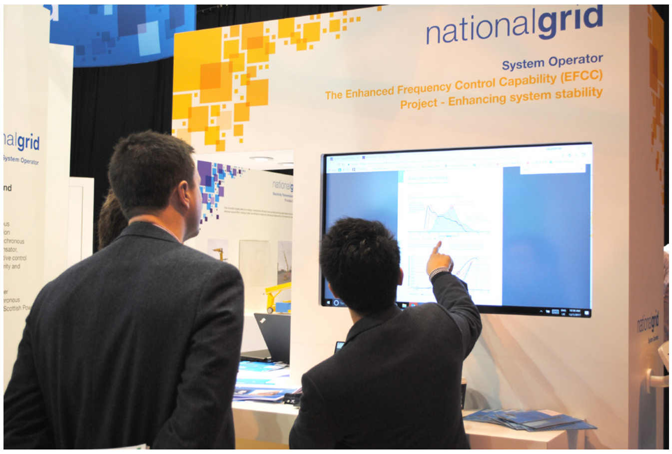
The second element of the conference was our exhibition stand. Our two academic partners assisted our presence at the LCNI Conference by delivering demonstrations on the stand.

The University of Manchester demonstrated their Hardware-in-the-Loop (HiL) capabilities by showcasing their testing and validation of the GE Grid Solutions' MCS. Different scenarios of frequency events and faults were demonstrated using a GB network model.

The University of Strathclyde provided an interactive demonstration that showed delegates the impact of lower system inertia on frequency control and how the proposed monitoring and control system could help to restore and maintain system frequency more effectively. This was demonstrated using interactive graphs; delegates could configure the system (i.e. input different demand levels, system inertia and so on) and see the differences in rate of change of frequency (RoCoF) and system frequency for the same event.

To enhance our profile within the industry, and promote our attendance at the LCNI Conference, a post for the ENA blog was written. This provided an overview of the project and what delegates could expect to see at the event. To generate as much reach as possible, the blog was live on the ENA LinkedIn and was shared via National Grid's social media channels including Twitter, LinkedIn and Facebook. The post can be read here: http://www.energynetworks.org/blog/





Awards success

Since June 2017 we have submitted the EFCC project into two internal awards within National Grid: the Chairman's Awards and the System Operator (SO) Awards.

Our 400 word submission for the Chairman's Awards was entered into the 'Fit for Future' category that celebrates new ideas and projects that demonstrate new ways of doing things.

The SO Awards were launched in 2016. They are one of a number of internal engagement campaigns held throughout the year to celebrate great success within the business area. Of the eight categories available, EFCC was entered into the 'Project/Initiative Success' category, the scope of which included leading the changes to the SO's future in the evolving energy networks and markets.

The project was also shortlisted in the 'Best Innovation' category at the Scottish Green Energy Awards 2017. These awards recognise and celebrate innovation, people and organisations that have ensured the success of Scotland's renewable energy sector.

While the project was not successful in these awards, at this concluding stage of the project delivery, the entries into each competition have provided good opportunities to engage with the industry and colleagues across National Grid, and the SO in particular, on the purpose of the EFCC project and the technical and commercial challenges it's tackling and the benefits it seeks to deliver.

Project website

Maintaining a good website is important. To make sure that we are connecting with our stakeholders, both current and new, we have updated the EFCC project webpages. Visitors to the website can now learn about the project at a high level or delve into more technical detail using the signposted tabs. These include finding out about project partners or learning more about the project and its different work packages.

We have included a 'news' page that allows stakeholders to follow our external engagement activities and a 'contact us' page that links to our project email address so that readers can send questions directly to the project team. An example is shown in Figure 1 below.

A new Group section of the National Grid website has been created. In line with this National Grid update, new EFCC webpages have replaced the previous design. The new webpages can be found here: http://www.nationalgrid.com/efcc

The EFCC project's communications lead will be trained on the new platform, 'beta', to ensure the content and visual design is continuously managed and up to date.

Further reference to our project webpages can be found on the National Grid LinkedIn profile. Updates about events, meetings, publications or any other activity that we would like to share are posted on the National Grid Innovation showcase page. The EFCC project communications lead can source analytics from each post if required, such as the percentile level of engagement or how many clicked through to read the full message.

Statistics from the EFCC webpages show that between June and October 2017, page views peaked at just fewer than 40 hits per day. We received 626 unique views for the EFCC homepage. A unique view is the number of different IP addresses (i.e. users) that have viewed the page. This is shown in Figure 2 below and demonstrates a lot of interest in the project. These statistics will be a good baseline measurement so that we can monitor any increases in future.

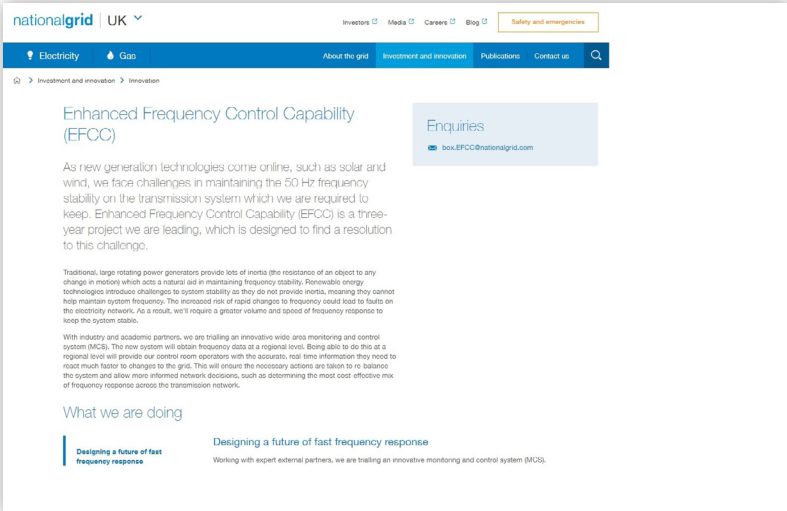
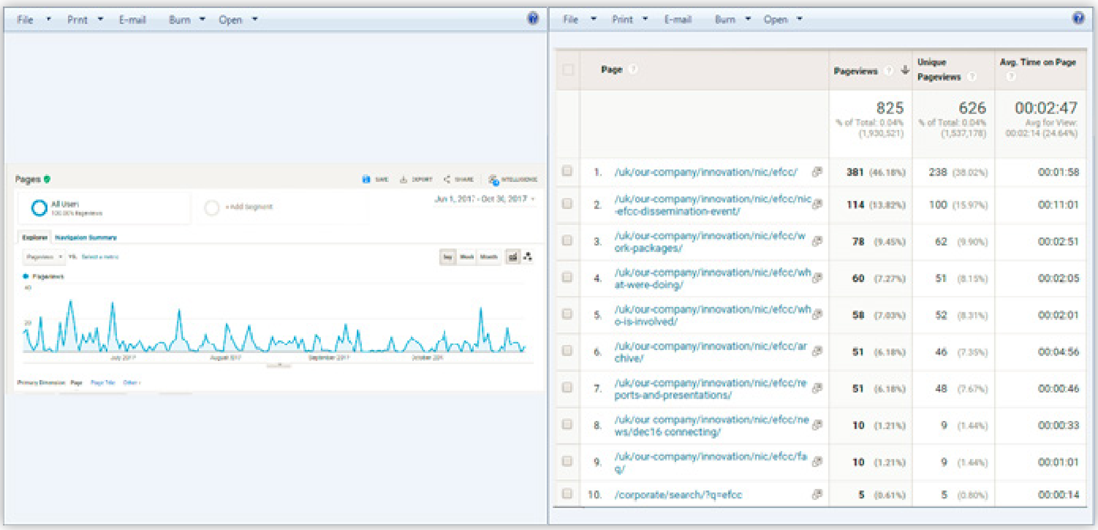


Figure 1. New EFCC webpages



	Page	Pageviews	Unique Pageviews	Avg. Time on Page
		825 % of Total: 0.04% (1,930,521)	626 % of Total: 0.04% (1,537,178)	00:02:47 Avg for View: 00:02:14 (24.64%)
1.	/uk/our-company/innovation/nic/efcc/	381 (46.18%)	238 (38.02%)	00:01:58
2.	/uk/our-company/innovation/nic/efcc/nic-efcc-dissemination-event/	114 (13.82%)	100 (15.97%)	00:11:01
3.	/uk/our-company/innovation/nic/efcc/work-packages/	78 (9.45%)	62 (9.90%)	00:02:51
4.	/uk/our-company/innovation/nic/efcc/what-were-doing/	60 (7.27%)	51 (8.15%)	00:02:05
5.	/uk/our-company/innovation/nic/efcc/who-is-involved/	58 (7.03%)	52 (8.31%)	00:02:01
6.	/uk/our-company/innovation/nic/efcc/archive/	51 (6.18%)	46 (7.35%)	00:04:56
7.	/uk/our-company/innovation/nic/efcc/reports-and-presentations/	51 (6.18%)	48 (7.67%)	00:00:46
8.	/uk/our company/innovation/nic/efcc/news/dec16 connecting/	10 (1.21%)	9 (1.44%)	00:00:33
9.	/uk/our-company/innovation/nic/efcc/faq/	10 (1.21%)	9 (1.44%)	00:01:01
10.	/corporate/search/?q=efcc	5 (0.61%)	5 (0.80%)	00:00:14

Figure 2. EFCC webpage statistics

Other communications activities

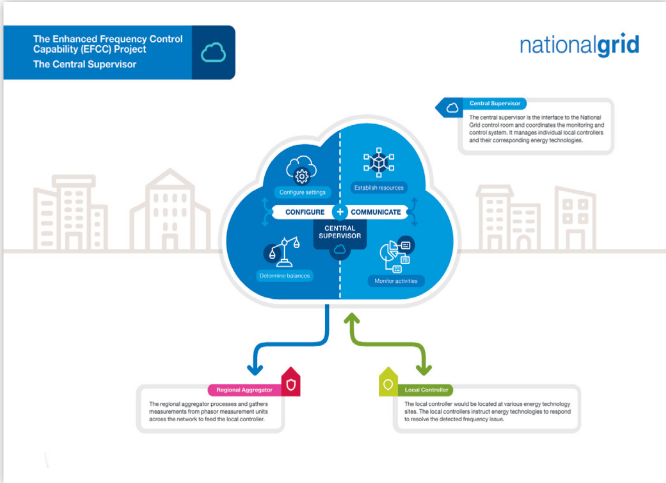
Within National Grid we continue to promote our activities with 'bite sized' project updates on our internal social networking site Yammer.

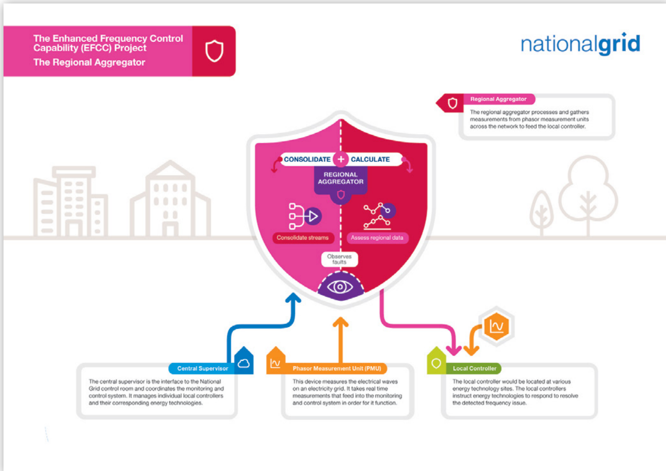
Monthly SO communications forums ensure the EFCC project's communications lead meets with the SO communications team and other communications staff from across the business to ensure that our plans are shared in a timely manner and that we are aligned with wider business messaging.

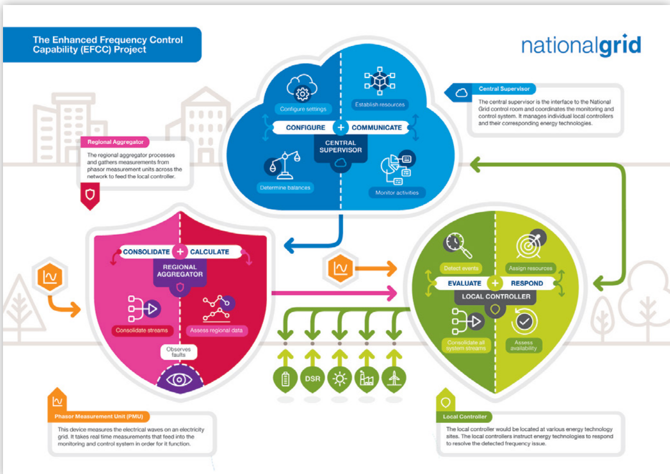
The project's communications plan has been refreshed and includes an activity tracker that all project members can contribute to. This allows visibility of communications activities and is structured to ensure we are always working with our business outcomes in mind and are referring back to our agreed main messages. It also accounts for metrics to ensure that we do not just communicate but also measure our effectiveness.

We share a communications update with all of our project partners at our steering group meetings and discuss any communication activities.

Finally, at the heart of the EFCC project is the development and demonstration of an innovative wide-area monitoring and control frequency response system. We know that this is a complex system so have created images to help explain the MCS and its constituent parts simply. These images were used at the LCNI Conference, both in the presentation session and on the exhibition stand, and in many internal communications within National Grid. The images are shown in Figure 3, below and to the right.







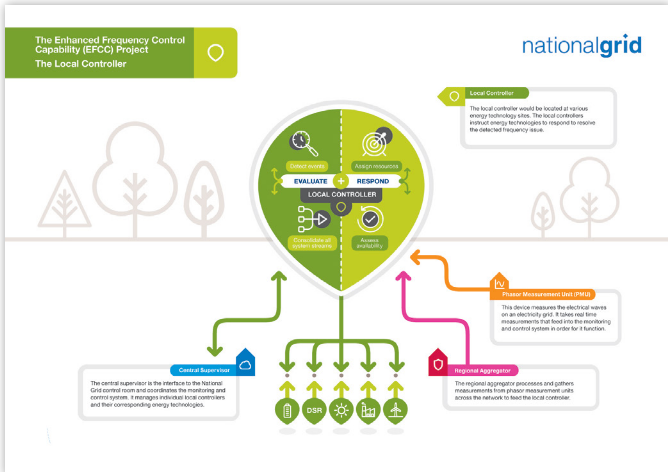


Figure 3. EFCC MCS images

Forecast for the next reporting period

The project activities for the next reporting period are shown in Table 3 below.

Table 3

Work package activities: January to March 2018

Work Package	Description	Partner	Comments	Status	Timescale
1	Monitoring and control scheme	GE Grid Solutions National Grid	Demonstration 4: installation, configuration and SAT of PMUs and monitoring and control applications for National Grid demonstration	Amber[*2]	Jan 2018 to Mar 2018
1	Monitoring and control scheme	GE Grid Solutions	Deliver control scheme data review report	Green	Jan 2018 to Mar 2018
2.1	Demand-side response	Flexitricity	Complete and analyse demand-side response field trials	Green	Jan 2018 to Mar 2018
2.2	Large-scale generation	Centrica	Complete and analyse large-scale generation field trials	Green	Jan 2018 to Mar 2018
2.3	Solar PV power plant	Belectric	Complete and analyse solar PV power plant field trials	Amber[*3]	Jan 2018 to Mar 2018
2.5	Wind	Ørsted Siemens	Complete and analyse wind field trials	Green	Jan 2018 to Mar 2018
3	Optimisation	University of Manchester	System studies on representative GB transmission network to assess proportionate responses from service providers and develop an optimal supervisory control strategy	Amber[*4]	Jan 2018 to Mar 2018
4	Validation	University of Manchester University of Strathclyde	Implement monitoring and control system for HiL and PNDC testing and validate the monitoring and control system	Amber[*4]	Jan 2018 to Mar 2018
6	Commercial	National Grid	Assess the economic value of a new rapid frequency service	Amber[*5]	Jan 2018 to Mar 2018
7	Communications	National Grid	Evaluate the communication infrastructure requirements and assess the current technical capabilities of the system. Co-ordinate installation of additional PMUs at National Grid substations to increase wide-area monitoring capability	Green	Jan 2018 to Mar 2018

Status	Description
Red	Unlikely to complete by due date
Amber	Minor issues but expected to complete by due date
Green	On track to complete by due date

[*2] This activity is amber because of the delay in establishing an appropriate demonstration scheme and the potential new requirement for GE Grid Solutions development of the PhasorController IEC 61850 MMS client interface.

[*3] This activity is amber because of commercial issues concerning remuneration of the solar PV owner during EFCC trials. This is expected to be resolved shortly.

[*4] These activities are amber because throughout testing a number of issues with the EFCC scheme have been identified. This has led to the implementation of new PhasorController software to fix these issues, which has caused delay due to additional and repeat testing. However, this experience has also provided useful learning related to the practical applications of the EFCC scheme and de-risking in advance of field trials and actual implementation. The affected work packages continue to be reviewed to make sure that the necessary study analysis is completed.

[*5] This activity is amber because of the delay in recruiting appropriate commercial resources. The affected work package continues to be reviewed to make sure that the necessary analysis is completed.

Business case update

Work package 2.4: Battery storage

National Grid has approved NIA funding internally to cover the costs of leasing the Belectric battery storage unit during the EFCC trials. This proposal maintains the overall EFCC objective and maximises what we can learn from investigating hybrid battery storage and solar PV compared to options involving battery storage only.

This decision was approved because changes in the project's approach and the energy landscape have removed much of the risk to consumers:

- leasing the Belectric battery storage unit significantly reduces the value of funds sought
- recent changes in the energy landscape have identified an increased requirement for flexible generation. New storage technologies – particularly batteries – are emerging into the market and there's a lot of discussion within the industry about their future role and the options they could bring to the electricity sector.

Contractual arrangements between Belectric and National Grid have been concluded. The Belectric battery storage unit is now installed onsite and is being commissioned. It is anticipated that EFCC battery storage trials will be able to start in early 2018.

Progress against plan

The project continues to make steady progress against our original plan. All notable achievements and events from this reporting period, including a full list of our forecast activities for the next reporting period, have been provided within the project manager's report section of this document.

Progress against budget

Project expenditure is within the budget defined by the Project Direction. Table 4 details the project expenditure to 17 November 2017, and highlights any variances against the budget.

Table 4
Proposed and actual spend: January 2015 to December 2017 (£000s)

Cost Category	Actual	Budget	Variance
Labour	1023.6	1969.2	(945.6)
Equipment	485.8	574.0	(88.2)
Contractors	1697.0	2119.6	(422.6)
IT	86.0	86.0	0.0
IPR costs	0.0	0.0	0.0
Travel and expenses	75.3	118.0	(42.7)
Payments to users	219.0	653.0	(434.0)
Contingency	164.0	621.3	(457.3)
Decommissioning	24.0	24.0	0.0
Other	51.5	40.0	11.5
Totals	3826.2	6205.1	(2378.9)

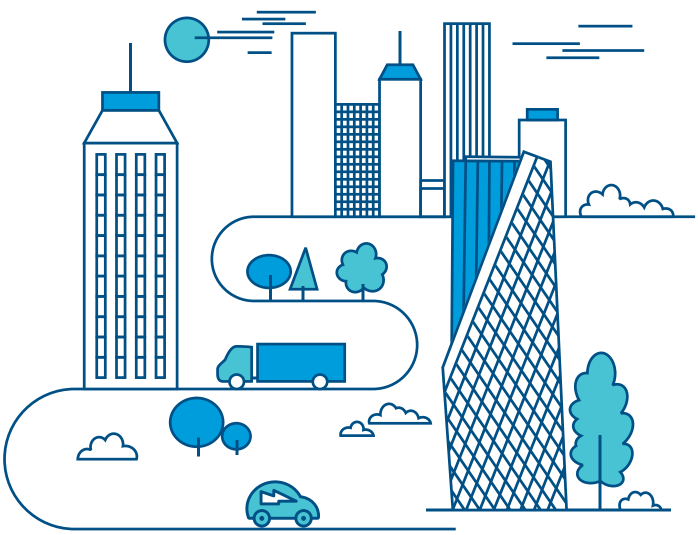
Our labour needs are monitored regularly to make sure that the right resources are allocated to the project. These costs remain under budget over the full lifecycle of the project. The recruitment process has been completed with additional resources secured.

The payment dates for contractors, travel and expenses and contingency have been realigned to the revised project delivery timelines. The higher than anticipated spend in the other category is due to the revised timeline for work package 2.5: wind. The overall spend for this category remains within budget over the entire duration of the project.

The actual spend on payments to users is consistent with the revised schedule for the project field trials, including the revised number of third parties taking part in work package 2.1: demand-side response.

Project bank account

Bank statements have been provided to Ofgem. Due to the confidential nature of the project bank statements, these have been included within a redacted appendix of this report.



Successful delivery reward criteria (SDRC)

GE Grid Solutions

The following work relates to the SDRC led by GE Grid Solutions during this reporting period. The document detailed below is covered by GE Grid Solutions' background intellectual property rights so cannot be published on the project's knowledge sharing website.

Work package 1: Monitoring and control system – control platform development – revision completed

GE Grid Solutions delivered a report to project partners describing the revisions made to the PhasorController software platform that was initially released in August 2016. This report was issued on 26 July 2017.

All project partners

All other remaining SDRC activities from within this reporting period are ongoing and have either passed their original due date or are unlikely to be completed by their original due date. However, it is anticipated that all of these SDRC activities will still be finished before the project ends in March 2018. Nevertheless, the project steering committee continues to evaluate all options available including the possibility of seeking a project extension from Ofgem. For further information please see Table 1 within the project manager's report section of this document.

Successful delivery reward criteria for the next reporting period

There is one SDRC due in the next reporting period of January to March 2018, as shown below in Table 5.

Table 5

SDRCs for the next reporting period: January to March 2018

Description	Due Date	Status	Comments
Report with recommendations regarding implementation of the new service	31 January 2018	Green	-

Future successful delivery reward criteria

There are no further SDRCs beyond those listed above. There does however remain the annual requirement to host a project knowledge dissemination and stakeholder engagement event.

Data access details

Network licensees must make clear how any network or consumption data they gather in the course of a project can be requested by interested parties. From 30 September 2017, network licensees must have in place a publicly available data sharing policy setting out the terms on which such data will be provided. National Grid's data sharing policy relating to NIA and NIC projects can be found at: https://www.nationalgrid.com/sites/default/files/documents/National%20Grid%20NIC%20and%20NIC%20Data%20Sharing%20Policy%20September%202017.pdf

Ofgem expects network licensees to share network and consumption data if the party requesting it can demonstrate it is in consumers' interests to do so subject to anonymisation and/or redaction for reasons of commercial confidentiality or other sensitivity.

For further information, please contact the project team via email at box.EFCC@nationalgrid.com.

Learning outcomes

This section describes what has been learned in the project during this reporting period.

Work package 1: Monitoring and control system

During the validation phase, settings management proved to be a key topic, as settings define the behaviour of the system as well as its response. During this reporting period, GE Grid Solutions collaborated with National Grid and project partners to establish recommended baseline settings. These settings will require a monitoring stage followed by fine-tuning after control scheme data and system performance reviews.

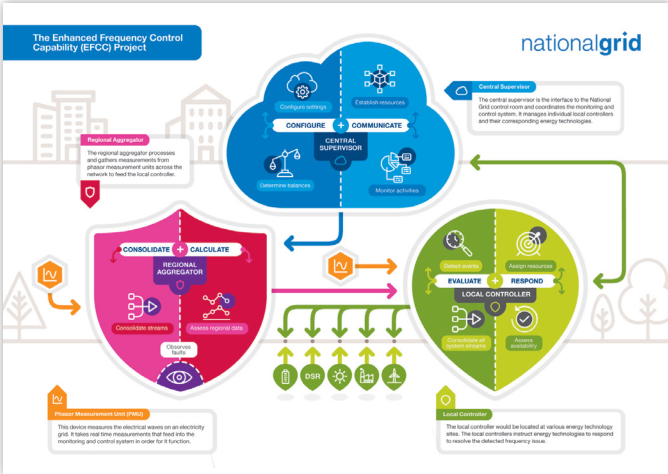
Information from technical field trials and future deployment schemes will provide the opportunity to tailor settings for the GB power system and its changing landscape. The schemes are undergoing a data-collection period where the installed devices will record local data which is reviewed to ensure the settings are suitable for the site. Through this mechanism, the project will learn about the scheme behaviour within the real system and begin to influence the scheme through these settings. The management of the settings will migrate towards the system operator for centralised control and an important learning has been to understand which settings should remain in the controller of the local resource owners and which should be in the control of the system operator.

During the installation and demonstration stages, for each new installation, the configuration is typically quite involved. This is because this project has different resources and different interfaces for each installation. Often this is new for the resource owners also, which adds time during installation. Also, the protocols being used are not typically used by the resource owners, for example IEC 61850, which means new configurations and protocols for the associated IT teams too.

It has become clear that installations into a business-as-usual deployment will need dedicated operations/IT teams to both design the interfaces and support the installations, particularly when much wider networks will be involved.

During installation and configuration, it has been identified that the platform itself can be difficult to configure. This has led to redesign of the key configuration interface on the platform to allow users to use and configure the platforms much more readily. This was rolled out to partners as part of a firmware update.

The complexity of the concept, the application function blocks and the monitoring and control system is significant. Training for National Grid and service providers needs to be tailored to make sure that technical resources can install, operate, monitor and maintain monitoring and control devices independently.



Work package 2.1: Demand-side response

The process of developing a site-deployable engineering solution for four different dynamic RoCoF loads was highly instructive. We used this part of the project to address the specific matter of deployment cost, in order to maximise the range of potential sites that could take part in EFCC services. We found the limits of low-cost, off-the-shelf hardware but were able to develop potential solutions to these at reasonable cost. These were successfully bench-tested and are now deployed on real EFCC loads for the trial period.

Our second spinning inertia site allowed us to use an alternative technology to measure the behaviour of CHP engines in response to rapid frequency deviations. We are accumulating data and will report on these in due course.

An unprecedented number of conventional frequency response events, typically resulting from the unreliability of the cross-channel interconnector, have caused some difficulties for static RoCoF trial participation. Nevertheless, we were able to continue the site trials in a disarmed configuration.

With all EFCC strands (static RoCoF, dynamic RoCoF and spinning inertia) now deployed on real industrial and commercial sites, and with a considerable volume of trial data already gathered, the final period of the project will focus on accumulating additional data, analysis and reporting.

Work package 2.2: Large-scale thermal generation

Centrica's activities during this phase of the project centred on preparing for site acceptance testing of the locally based PMU. This involves installing the PMU at South Humber Bank with appropriate connectivity to the South Humber Bank CCGT DCS and the National Grid at 400kV via Current Transformers (CT) and Voltage Transformers (VT) at the South Humber Bank 400kV substation. This latter connection required the installation of fibre optic cable within the power station site. A satellite connection was also needed for time stamping data.

With the assistance of GE Grid Solutions site acceptance testing was successfully completed on 22 November 2017.

As previously reported, the revised frequency control logic, using RoCoF as an input rather than deviation in frequency from 50.0Hz, is installed in one (GT-21) of the two gas turbines at South Humber Bank power station. While this logic is not driving the response of the plant, it is working in a passive mode so we can review any significant frequency deviations that occur on the National Grid and look at how the conventional frequency response logic would have driven the plant, as well as how the revised frequency control logic would have driven the plant.

Review of these events has been encouraging and consistently shown that the revised frequency control logic will give more response in the early stages (sub 10 seconds) of a significant frequency event. This review is also shared with the wider EFCC project team, promoting good discussion and furthering the team's understanding of plant and system characteristics in frequency incidents.

After discussions with National Grid, we agreed on suitable arrangements for using the revised frequency control logic on GT-21 'in anger', while continuing to use the conventional frequency control logic on GT-22.

As with most CCGTs, the steam turbine plays little or no role in frequency response, particularly in the early stages of delivery. This will further enable us to evaluate how the revised frequency control logic behaves with real system frequency as an input and also to make a comparison between revised (GT-21) and existing (GT-22) frequency response logic based output. This is likely to take place in early 2018 and we hope to present the findings at the March 2018 knowledge dissemination and stakeholder engagement event.

On 1 September 2017, Energetický a Průmyslový Holding (EPH), a leading Central European energy group that owns and operates assets in the Czech Republic, the Slovak Republic, Germany, Italy, the UK and Hungary, bought South Humber Bank power station. Centrica are continuing to manage and provide technical input to the project on EPH's behalf. Under this arrangement, the project should be concluded as normal.

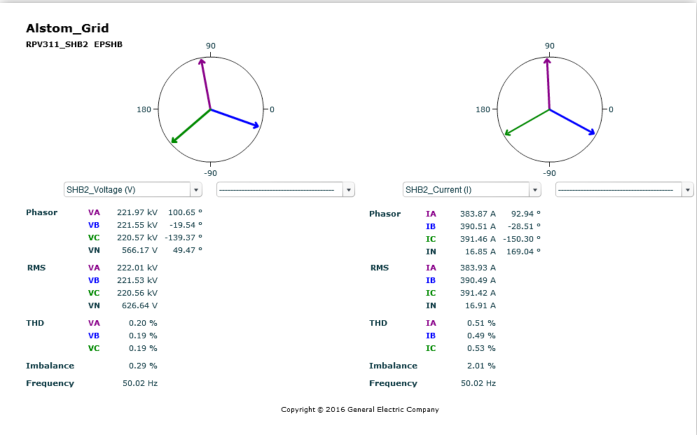


Figure 4. PMU readings of voltages and currents measured at South Humber Bank 400kV substation

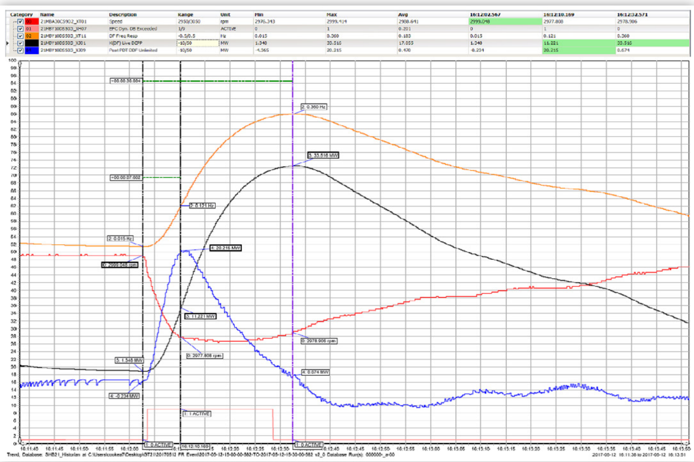


Figure 5. Plot of revised frequency control logic response (blue line) to an actual system event compared to existing frequency control logic response (black line)

Work package 2.3: Solar PV

Belectric carried out the following activities during this reporting period at the Rainbows solar PV power plant:

- continued to develop the software for the Belectric hybrid controller and the control algorithms
- improved the accuracy of the solar power forecasting. This involves a cloud movement camera and an advanced solar PV model in combination with the Belectric hybrid controller. These are used to calculate the resource attributes at any moment in time
- improved the communication commands between the inverters and the hybrid controller in order to move the maximum power point of the solar PV plant so it will react more effectively to commands from the GE Grid Solutions local controller
- detected flawed equipment, repaired and reinstalled it, reducing the error rate within the communication chain
- developed and shared a test plan to demonstrate the frequency response capabilities of the solar PV power plant
- prepared a combined test plan with National Grid. It is hoped that the solar PV power plant will be tested within the National Grid architecture of central supervisor, regional aggregators and local controllers.

The following learning outcomes were achieved during this reporting period:

- positive and negative frequency response is possible from solar PV but only by integrating a cloud movement camera and a solar PV model into the Belectric hybrid controller. This can be achieved by shifting down the operating point of the solar PV plant. However, this is a cost-intensive solution that can be applied only for short periods of time
- the implementation and use of the new communication protocol IEC 61850 GOOSE between the Belectric hybrid controller and GE Grid Solutions' PhasorController proved successful
- the integration of GE Grid Solutions' PhasorController, PMU equipment and PhasorPoint measurement software was demonstrated and is working with the Belectric controller components within the solar PV power plant.

Also, as explained earlier in this report, we are pursuing the concept of a Belectric hybrid solar PV and battery storage resource and it will be tested during the next phase of the project. In continuing to work towards this, the following objectives and outcomes were achieved during this reporting period:

- the combination of solar PV and battery storage can provide a positive and negative frequency response with more regulating power and at a lower cost than by using only solar PV
- the Belectric Energy Buffer Unit (1MW/1MWh) has been deployed and is installed onsite close to the solar PV power plant. Commissioning activities will follow shortly
- the communications infrastructure is being installed
- the grid connection point and Western Power Distribution substation is installed and energised
- contractual discussions between Belectric and National Grid have concluded
- combined solar PV and battery storage test plans are being prepared.

Work package 2.5: Wind

During this reporting period, work has continued with DONG Energy, now known as Ørsted, and Siemens Gamesa Renewable Energy (SGRE) to test a windfarm's ability to provide fast, initiated frequency response. A stage-one contract was signed in October 2016 for inertial response trials to take place on an SWT-7.0-154 test turbine. A stage-two contract for trials on a commercially operational windfarm is still being discussed.

The outstanding challenge in finalising the stage-two contract is to determine how liabilities will be shared during these activities. In the meantime, to develop an understanding of current windfarm frequency response capabilities, prior to any possible stage-two trials, Frequency Sensitive Mode (FSM) was tested using more severe settings than the norm at the Ørsted Burbo Bank windfarm.

The stage-one activities achieved the following:

- asset integrity field trials for the inertial response function of an SWT-7.0-154 test turbine validated that the loads experienced are inside acceptable levels to proceed with more detailed field trials using this turbine model. This inertial response testing was concluded in June 2017

- multiple detailed inertial response field trials on an SWT-7.0-154 test turbine determined the functional capabilities of a single turbine at various power ranges and wind conditions. These results were aggregated to simulate an entire windfarm's response. This testing was concluded in August 2017

- FSM field trials at the Ørsted Burbo Bank windfarm were executed for a range of response parameters to investigate current windfarm capabilities with a key focus on performance

- simulations were run to get an estimate of the expected performance in the entire wind range. These simulations used the BHawC aero-elastic code, a validated structural model of the SWT-7.0-154 turbine and the turbine controller

- presented asset integrity field trial and subsequent simulation results and an early Ørsted portfolio analysis at knowledge sharing and dissemination events. The detailed inertial response field trials indicated that ten percent inertial response magnitude for ten seconds might not be available at all production levels. Analysis has shown that five to six percent is a realistic setting with the current inertial response function.

  However, further trials and function development is needed. In addition, Ørsted will also, as part of the stage-one work, assess the overall volume of response that can be achieved from the proposed scheme on its portfolio of wind and the commercial implications of doing so. In their assessment, Ørsted will use the average magnitude of inertial response for ten seconds.

Finally, as reported previously, the use of a GE Grid Solutions' PhasorController during these windfarm trials is no longer within the project scope as the central windfarm controller is capable of measuring the power system frequency and instructing the windfarm to provide the required frequency response in the specified form.

Work packages 3 and 4: Optimisation and validation
(1) The University of Manchester

Work package 3: Optimisation

The University of Manchester has focused on developing an optimal supervisory controller in DIgSILENT PowerFactory. In this activity the Kundur two area power system model was used as the test system to perform non-linear time domain simulation studies. More precisely, a linear state-space power system model candidate was designed. This is a prerequisite to the development of a Linear Quadratic Gaussian (LQG) controller that will be used as a supervisory controller in our studies.

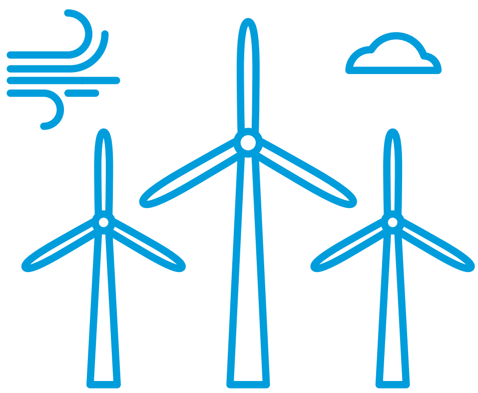
Having obtained a linear power system model, an LQG controller was designed and tuned, based on the performance of the linear model and then integrated back to the non-linear power system model, which was designed in DIgSILENT PowerFactory. Using the LQG controller will show how the supervisory LQG controller can assist system frequency response by generating additional control input signals to the governors of synchronous generators.

The test power system model was modified to include service providers such as energy storage, solar PV systems and wind farms. This is to represent the high penetration of inverter based generation in future, low inertia power systems.

Following the methodology described above, a linear state-space power system model candidate was developed that accurately describes the dynamic nature of the actual power system. Based on the linear model, an LQG supervisory controller was designed that ensures an optimal co-ordination among the service providers to achieve a better frequency response of the system (i.e. smart frequency control).

This is obtained through optimal control input signals being sent from the supervisory controller to the local controllers of the service providers that then controls the active power output of the service providers in such a way as to assist system frequency response. Various system frequency response simulation studies have been performed to validate the effectiveness and reliability of the LQG supervisory control scheme.

Having obtained successful results of the new LQG supervisory controller for optimally co-ordinating the service providers, the proposed methodology is now being applied to a larger scale power system model such as the IEEE 10 machine, 39 bus power system model, modified to include service providers, to confirm the effectiveness of the proposed LQG supervisory control scheme for assisting system frequency response.



Work package 4: Validation

The University of Manchester's work and learning during this reporting period focused on system studies and service provider modelling in DIgSILENT PowerFactory and Real Time Digital Simulator (RTDS) HiL testing. Both non-real-time and real-time tools were used to test and validate the performance of the integration of different service providers, local and wide-area smart frequency control and the GE Grid Solutions' monitoring and control system.

a) Validation activities through system studies in DIgSILENT PowerFactory

(i) Integration of solar PV into the representative two-area and 36-zone GB test power networks and assessment of frequency response

A model of a solar PV system was developed to study its short-term dynamic response to system frequency deviations. The focus was on describing the main component of the solar PV system and its relevant equations. The team also investigated available inertial and droop response based on de-loading the solar PV system to help support primary frequency control in power systems.

The model was used in conjunction with a simple but practical two-area Klein-Rogers-Kundur (KRK) and 36-zone GB power system model in DIgSILENT PowerFactory to study the impact of increasing levels of wind energy conversion systems and solar PV generation on frequency control. CCGT influences were also considered. Modal analysis and dynamic time-domain simulations were done to study power system frequency response and investigate how solar PV systems can impact this response on a test power system with high penetration levels of wind energy conversion systems. The impact of different parameters related to solar PV systems on primary frequency control capability was also evaluated.

(ii) Integration of battery energy storage system into the representative two-area and 36-zone GB test power networks and assessment of frequency response

A model of a battery energy storage system was developed to study its short-term dynamic response to system frequency deviations. The focus was on describing the main component of the battery energy storage system and its relevant equations.

The team also investigated available inertial and droop response from the battery energy storage system to help support primary frequency control in power systems. The model was used in conjunction with a simple but practical two-area KRK and 36-zone GB power system model in DIgSILENT PowerFactory to study the impact of increasing levels of wind energy conversion systems and solar PV generation on frequency control.

Modal analysis and dynamic time-domain simulations were done to study power system frequency response and investigate how battery energy storage systems can impact this response on a test power system with high penetration levels of wind turbines and solar PV systems. System frequency response following several contingency events was also tested using time-domain simulation under high penetration levels of renewable energy sources. The impact of droop parameter and installation location of the battery energy storage system was also evaluated.

The single line diagram of the two-area system in DIgSILENT PowerFactory with battery energy storage, CCGT, solar PV and wind integrated is shown in Figure 6 below.

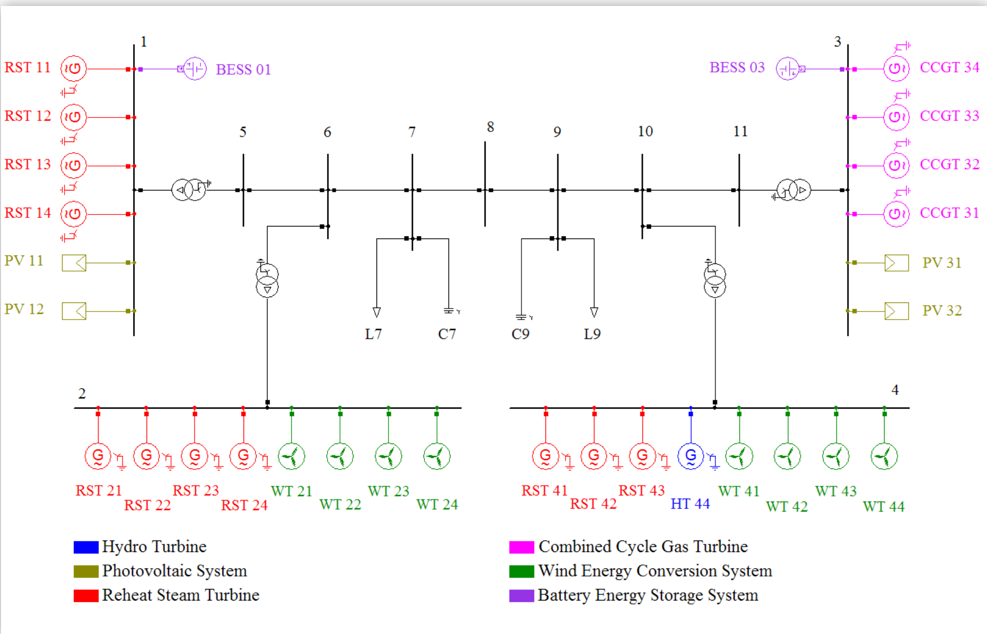


Figure 6. Single line diagram of the two-area system in DIgSILENT PowerFactory

(iii) Modelling local and wide-area smart frequency control operations

Local: based on knowing the maximum delta P deployment for the system before the fault and the RoCoF calculated for the centre of inertial mass, this algorithm would deploy the appropriate scale of response in sufficient time. This is delivered based on an 'event trigger' using RoCoF and absolute frequency measured in a defined period that can be up to as long as the load has to respond. The volume of response deployed by zone is dependent on the RoCoF.

Wide-area: a wide-area calculation identifying the centre of inertia RoCoF and the level of response to be triggered by the resources closest to the disturbance as well as equal allocation of response across all zones. In principle this would be similar to the GE Grid Solutions' monitoring and control system, but less complex in its coding.

The objective is to see if this 'simple' system, which would be less reliant on wide-area communications and real-time calculations, will see a regionally different RoCoF across the system during an event and whether it deploys enough frequency response fast enough in practice. It should be noted that a short time interval or window for the RoCoF calculation can provide poor and unreliable estimation. In the proposed algorithm, an adopted 'growing window' method is used to improve the RoCoF estimation accuracy.

The measurement window is delayed by at least 140ms to avoid transient domain issues. An average RoCoF over a measurement window of 500ms is measured. Based on GC0079*, a low frequency relay would trigger within 130ms of being signalled for a static service, like the tripping of demand, plus a 200ms cushion period to cover signalling and delivery. Thus a communication time delay has been considered in the development of these smart frequency control schemes.

b) Validation activities through RTDS HiL testing

A RTDS is used for HiL testing and validation of the monitoring and control system that has been developed by GE Grid Solutions. The aim of the University of Manchester within the EFCC project is to provide expertise and equipment that enables a range of HiL testing through a variety of system cases and operational conditions. Those scenarios and system cases would be impossible to execute in real-world field trials but will be examined using real-time simulation facilities in Manchester.

In order to fulfil the validation activities, high quality models were developed in RTDS. These models are a two-area test system and a simplified 36-zone GB network model. Service provider models were also developed and integrated with the network models. The HiL testing focused on testing all Application Function Blocks (AFBs) of the GE Grid Solutions' PhasorControllers and testing the entire monitoring and control system to assess EFCC response.

* https://www.nationalgrid.com/uk/electricity/codes/grid-code/modifications/gc0079-frequency-changes-during-large-disturbances-and

(i) Testing all AFBs of GE Grid Solutions' PhasorControllers

HiL testing using the standard 2-area test system model is performed to assess a range of system cases and operational conditions in RTDS and to test the functionality of the developed AFBs. The functionality of the AFBs of the local controller, regional aggregator and central supervisor has been implemented on the hardware platform using the PLC environment and will be tested and validated. The AFBs of the PhasorControllers that were developed by GE Grid Solutions and tested by the University of Manchester are:

- in the local controller: System Frequency Aggregator AFB, System Angle Aggregator AFB, Event Detection AFB and Resource Allocation AFB functionalities
- in the regional aggregator: Regional Angle Aggregator AFB, Regional Frequency Aggregator AFB and Fault/Open Line Detector AFB functionalities
- in the central supervisor: Optimisation AFB functionalities.

The main functionality of the event detection AFB and the resource allocation AFB will be validated using the GB network test system model that was developed in RTDS. The entire monitoring and control system will also be tested. The tests that were performed for each of the AFBs and their functionalities were presented in a report that has been submitted to National Grid. For each test, the AFB and its setting variables are briefly described, along with the test procedure, and the expected result is compared against the actual result.

During testing a 'bug' or missing logic within the central supervisor was found and reported to GE Grid Solutions. Modification was later proposed by GE Grid Solutions and this was applied in Straton. The issue was that the resource allocation AFB sent values of 'response time for positive power' and 'response time for negative power' in milliseconds while the central supervisor required these values in seconds. The additional logic that was added to the central supervisor to overcome this issue is shown in Figure 7 below.

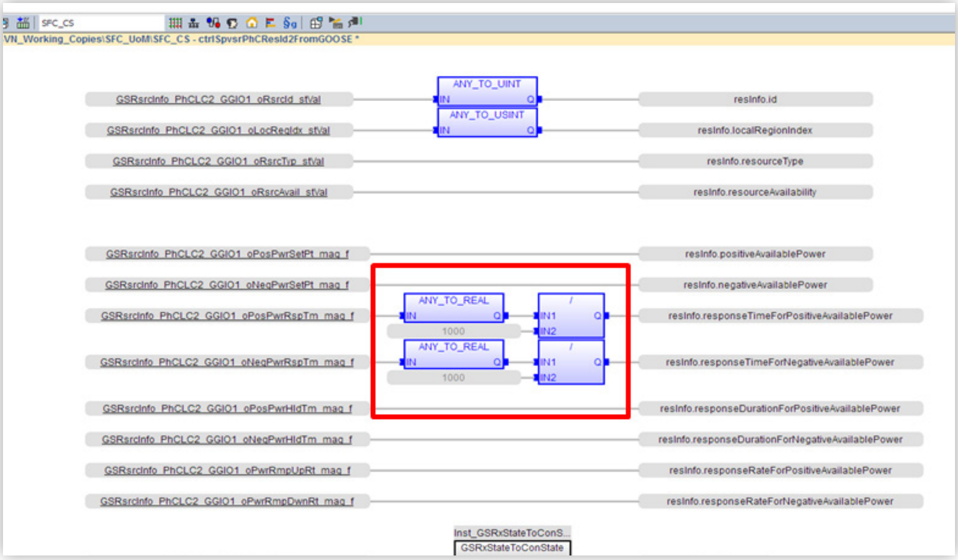
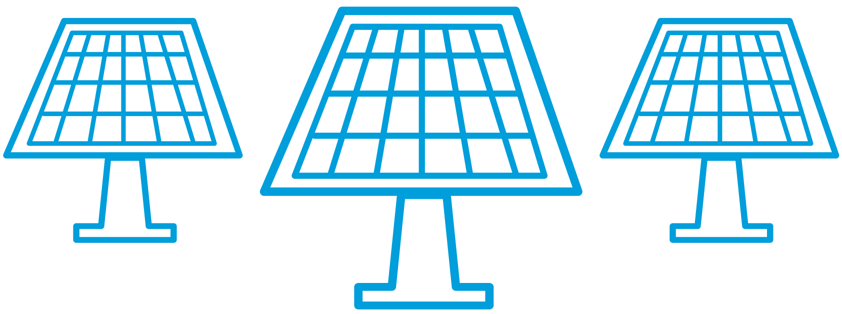


Figure 7. Additional logic added to the central supervisor



(ii) Testing resource allocation AFB and the entire monitoring and control system

The resource allocation AFB is responsible for the relationship between the central supervisor and the local controller in building up resource portfolios. The resource allocation AFB is also responsible for the initiation of control actions and how that action is allocated across the different resources in the system. The main functionality of the resource allocation AFB however, is to estimate the power imbalance of the power system and to determine the targeted region and proportional response to an event.

Instead of testing the resource allocation AFB in the 2-area system, it is better to test it in the GB network test system model as its main function is to estimate power imbalance and to determine how active power response will be released. In the GB network test system model, five categories of test were designed and conducted:

- load increments of various sizes at different locations
- faults (single line and 3-phase to ground) with different fault durations at different buses
- successive events after a fault (i.e. a generator tripping after a fault)
- the impact of ramped disturbances on the monitoring and control system
- the impact of PMU weights on system frequency.

The results such as system frequency, system RoCoF, event detection, fault detection, response of service provider and other variables will be obtained from the GE Grid Solutions' PhasorControllers and RTDS and will be summarised and reported.

A final update of the event detection AFB and new firmware for the PhasorControllers was received from GE Grid Solutions and installed on 30 August 2017. Therefore the functionalities of the new event detection AFB will be tested using the GB network test system model and presented in the final report.

It should be noted that there was a problem of frequency spikes and fake RoCoF in the original event detection AFB. The University of Manchester solved this problem, with support from GE Grid Solutions, by changing the setting value of sFrqChgThr within the event detection AFB. Frequency spikes are caused by a sudden phase shift in the voltage waveform from virtual PMUs in the RTDS.

Lessons learned from HiL testing will be significant and will be reported via EFCC project reports, at EFCC knowledge dissemination and stakeholder engagement events, at international conferences and in peer-reviewed journal publications.

(2) The University of Strathclyde

Work package 4: Validation

During this reporting period the team at the University of Strathclyde carried out exhaustive tests of the EFCC PhasorControllers based on a comprehensive test programme agreed by project partners. These tests used a flexible Power-Hardware-in-the-Loop (P-HiL) testbed to emulate realistic grid frequency disturbances and which couples the 11kV physical network at the University of Strathclyde's Power Network Demonstration Centre (PNDC) with a reduced GB transmission network model executed in the Real Time Digital Simulator (RTDS).

This testbed allows the PhasorControllers to receive measurements from PMUs installed in a physical network as opposed to a purely simulation-based environment, which may be less credible, and control the physical load banks, emulating a demand-side resource, to provide controllable frequency response.

The test activities at the PNDC include validation of the EFCC scheme when operating in local mode, when the wide-area communication signals are lost and/or are of poor quality; when operating in wide-area mode, when all of the communication links are available; and to test the impact of communication system performance on the operation of the EFCC scheme.

(a) Validation of the EFCC scheme in local mode

Figure 8 shows the test configuration at the PNDC for investigating and evaluating the local operational mode of the local controllers. The motor-generator set is controlled to replicate frequency disturbances. A physical PMU is connected to the network collecting the local measurement data for the local controller. The load bank acts as the resource to be controlled by the local controller. Using this arrangement, the team conducted a wide range of tests of the local controllers performance in response to under and over frequency events. Physical faults have also been applied in the network to test the security of the system during non-frequency events.

This phase of tests has been completed and the issues identified generated useful learning and knowledge of the scheme's behaviour. It also allowed GE Grid Solutions to revise and modify the software in revised versions of the system, thereby de-risking the overall scheme and ensuring it is in a higher state of readiness for in-field, 'live' implementation.

(b) Validation of the EFCC scheme in wide-area mode

The configuration for the wide-area mode tests is shown in Figure 9 where the 11kV network is coupled with a simulated transmission network (represented using a reduced GB grid model). Two local controllers are used, with one controlling the load banks of the PNDC's physical network and the other controlling a simulated resource represented in the RTDS simulation. These local controllers receive measurement data from three regional aggregators through an emulated wide-area communication network. An emulated central supervisor is used for supplying resource availability information.

During this reporting period, this test arrangement was used by the team to test the EFCC scheme's dependability in terms of responding correctly to actual frequency events and its security in terms of ensuring that it remains inoperative for non-frequency events.

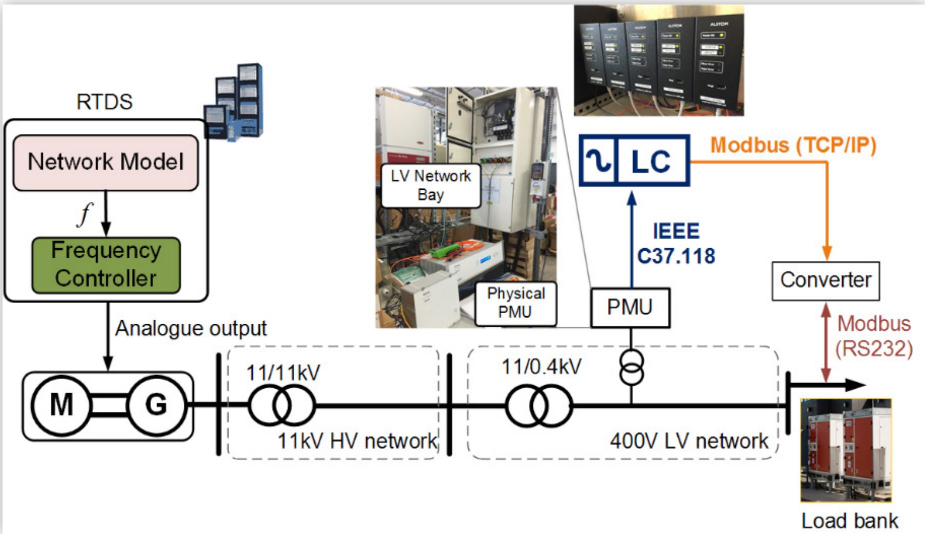


Figure 8. Schematic of the local operation mode test configuration

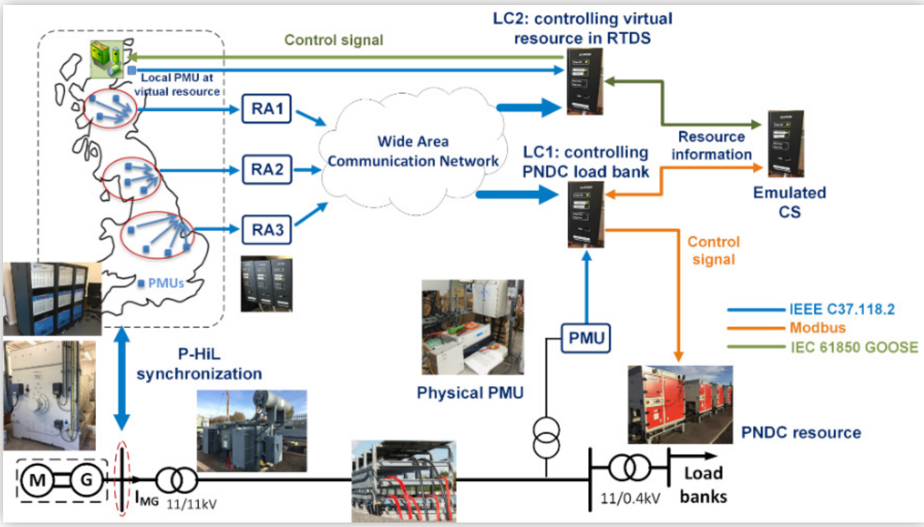


Figure 9. Schematic of the wide-area operation mode test configuration

(c) Testing the impact of communication system performance

A commercially available communications system emulator, which can support the degrade operation of a communications system, was used to emulate the wide-area communication network as shown in Figure 9. The team used it to emulate various network conditions including different levels of latency, jitter and data loss etc.

It has been established that when the communication network performance degrades below the tolerance level configured in the local controller (e.g. a latency greater than 200ms), the EFCC scheme will automatically switch to local operation mode as expected. These tests are ongoing to evaluate the impact of communication system performance over a wide range of scenarios.

(d) Knowledge dissemination

The team has also been working on disseminating the knowledge generated and the lessons learned from this project through a variety of publications and events. There is more about these activities in the knowledge dissemination section of this report.

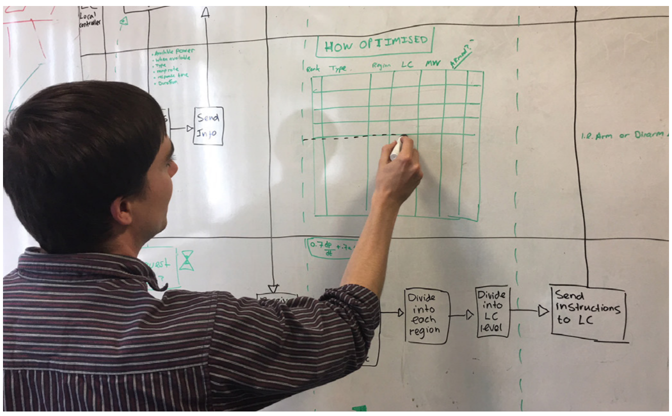
Work package 6: Commercial

This work package focuses on how faster/rapid frequency response could be developed and offered as a commercial service to the energy industry. The work package will align with other industry initiatives, in particular the product simplification strategy outlined in the Systems Needs and Product Strategy document.

The field trial test results will be provided to the wider industry review of balancing services that is being led by National Grid. The results will confirm what frequency response services different technologies could provide to help operate the electricity transmission system now and in the future.

The work package will focus on quantifying the value of faster/rapid frequency response to the National Electricity Transmission System Operator (NETSO) and what commercial opportunities such a service could provide to industry participants, both established and new. This assessment will be underpinned by a cost benefit analysis.

This will also consider what additional value the implementation of a monitoring and control system, with the ability to co-ordinate the dispatch of faster/rapid frequency response providers, could provide to the NETSO, including any associated cost savings. The results of this cost benefit analysis will be available in the project closure report alongside any proposed next steps.



Work package 7: Communications

The project continues to consider what is needed for the data communications infrastructure and associated changes to existing or new business processes, to support the GE Grid Solutions' monitoring and control system, should the scheme be adopted as a productionised, operational service.

Recent demonstrations at the University of Manchester and the University of Strathclyde's PNDC have been essential in providing and validating National Grid's understanding of the system processes, operation and configuration. The roles and responsibilities of each system component and how they communicate with one another have also been clarified.

National Grid has been able to model and document the current end-to-end processes and is now aware of the data flows, technical architecture and communication protocols. The system processes and data models were reviewed with GE Grid Solutions during a November workshop and are now being refined. When this is finished it will facilitate the subsequent impact assessment on existing business systems, services and processes. This impact assessment report is being written.

Demonstrations at the University of Manchester and the University of Strathclyde included running a series of test scenarios. This enabled National Grid to see how the system responded to different conditions, such as simulated system faults and frequency events, reinforcing understanding and determining areas for further investigation.

After these workshops, National Grid began to investigate and establish possible interfaces with, and impacts on, internal systems. We also began to technically assess how the monitoring and control system could integrate with the Electricity National Control Centre (ENCC). Information about this will be included in the project's closure report.

National Grid is currently assessing what the architectural and data communication options and requirements are to support any future operational control room integration.

National Grid Demonstration

National Grid will demonstrate the GE Grid Solutions' monitoring and control system using the central supervisor, regional aggregator and local controller units to understand how the existing communications infrastructure can support reliable operation of the developed control scheme. However, as the GE Grid Solutions' monitoring and control system is in the prototype stage, the demonstration will not directly interface with existing protection or other critical systems, in order to preserve the integrity of the transmission network.

The main aims of the National Grid demonstration are to establish:

- how the control scheme can be installed on the existing National Grid communications infrastructure while making sure that cyber security practices are met and determining the impact in terms of latency and lost data and/or signals
- the practical aspects of setting up communications links to resource providers to show how third parties could connect to the monitoring and control scheme to provide a frequency response service
- how the monitoring and control scheme responds to real frequency events using active measurements from PMUs and monitoring devices already installed at National Grid sites. In addition, simulated data from historical frequency events will be input into the PhasorControllers to test the control scheme and to reinforce the live system testing
- the performance of dynamic monitoring devices already installed on the transmission network in terms of how they connect with GE Grid Solutions' equipment and relaying electrical measurements to the monitoring and control scheme. Speed of data handling, data resolution and reliability can be ascertained to determine a minimum specification for reliable control operation
- how transmission system regional inertia estimates affect the operation of the monitoring and control scheme frequency response calculations with varying generation and demand patterns and define acceptable levels of error in order to evaluate operational consequences (i.e. the potential effect on control room frequency measures and National Grid processes).

Site surveys have started at the proposed substation locations for the regional aggregators at Grain, South Humber Bank and Walham 400kV substations. A local controller will also be installed at Grain and encoded to represent an interconnector (i.e. with similar power ramping characteristics pre-set to show the response to a frequency event).

This local controller will be connected via the communications network to the regional aggregator at Grain. Similarly, regional aggregators at South Humber Bank and Walham will aim to communicate with Centrica's CCGT and Belectric's solar PV plant via their respective local controllers. The central supervisor, sited at a National Grid location, will enable the monitoring and control system to be updated with regional inertia data to simulate how these values change during the day as well as receiving available power information from the local controllers.

The interface details with Centrica and Belectric are being developed and it is anticipated that the demonstration will be installed and configured in January 2018.

National Grid employees have received training from GE Grid Solutions for the configuration of the PhasorControllers, methods of inputting parameters and gathering output data. The PhasorPoint platform implemented as part of the NIC VISOR* project will be used to capture the output signals from each of the PhasorControllers used: central supervisor, regional aggregator and local controller.

* https://www.spenergynetworks.co.uk/pages/visor.aspx

Intellectual property rights

GE Grid Solutions and all other project partners will make versions of their reports and documents available on the project website wherever possible, in order to meet the requirements to publish intellectual property developed within this project. Full versions will be available to all project partners as part of the multi-party contract they signed. This approach to the review and publication of background and foreground intellectual property will be repeated on all documents produced throughout the project.

Risk management

Current risks

All project partners regularly monitor and review project risks. Crucial risks for this reporting period are detailed below and a full risk register can be found in Appendix C of this report.

Risk no.	Work streams /area	Risk description	Cause	Consequence	Risk owner	Likelihood (1-5)	Financial impact (1 - 5)	Reputational impact (1 - 5)	RAG	Escalation route	Action plan	Control opinion
18	General	Communications between devices underperforms.	Communication infrastructure is not fit for purpose.	The existing communication infrastructure may inhibit the speed of response of a control, reducing scheme effectiveness.	National Grid	5	5	4	25	Project manager	Work closely with National Grid and partners to make sure that new communications links not critical to project success. Make sure that the communications infrastructure is well understood and the chosen control scheme can best work with available infrastructure.	Partially Effective
19	General	Outage required for commissioning.	Inability to obtain the relevant outages for commissioning.	Possible delays to commissioning programme or cost of outage.	National Grid	5	2	4	20	Project manager	Outages identified and incorporated in scheme requirement document.	Partially Effective
63	General	General back loading of deliverables in the project.	Slippage against baseline for deliverables.	Compromising scope and quality of deliverables.	Project manager	5	4	5	25	Steering Group	NGET and partners have monthly review of planned deliverables, identifying any issues with delivery, investigating alternatives and escalating to Steering Group.	Partially Effective
69	WP6 - Commercial	Delay in delivering the commercial workpack.	Understanding the nature of the WP deliverables and unable to access specialist resourcing skills.	Work package is not delivered on time, undermining success of project.	Project manager	5	3	5	25	National Grid	Recruited specialist resource who will draw on existing expertise within NGET. Further recruitment ongoing. Will align with FRSO flexibility work stream (product simplification consultation) - resource field trials to input into consultation process. Develop further commercial work packages with EFCC infrastructure.	Partially Effective
70	WP2.2 - Large-Scale Generation	Centrica unable to take part in project and deliver WP2.2.	Centrica has sold CCGT which is used for trials.	Centrica do not complete trials, putting WP2.2 at risk of non-delivery.	Centrica	1	3	3	3	Steering Group	EPH have said several times that they want to continue on the project. Contractual details with EPH to be confirmed. Preferred option is EFCC contract with EPH South Humber Bank continues and EPH sub-contract with Centrica to continue to manage project. Terms for this have been drawn up but not yet signed.	Partially Effective
71	WP2	Non-delivery of a meaningful NG demonstration (simulation and/or network).	Lack of clarity in original submission and difficulty in differentiating NG demonstration from other partners' demonstrations.	Lack of evidence of how the system would operate in a real operational environment.	Project Manager	4	1	5	20	National Grid	1. NG technical resource has now been engaged to dedicate time and effort to this risk. 2. We shall approach other partners for support as required 3. Plan to be developed and implemented.	Partially Effective
77	WP7 - Comms	Existing telecommunications network and PMUs unable to support the developed MCS functionality for BaU roll out.	Incompatible communications protocols used plus differing ETO and SO priorities for the same fault recorder equipment with PMU functionality enabled.	Fault recorders and dynamic monitoring equipment process frequency data for system monitoring purposes. The project is unable to achieve the targeted speed of response times.	Project manager	5	4	4	20	National Grid	Feed outcomes of the NG demonstration into WP7 impact assessment.	Partially Effective

Accuracy assurance statement

This EFCC progress report has been produced in agreement with the entire project steering committee. All project partners have been involved in writing and reviewing it. The report has been approved by the EFCC project steering committee and by Graham Stein, Network Operability Manager, on behalf of Julian Leslie, Network Capability – Electricity Manager and the project sponsor. Every effort has been made to ensure that all information in the report is true and accurate.

Graham Stein
Network Operability Manager
National Grid

Appendices
Appendix A: EFCC project plan

Work package	Partner – activity	Oct '17	Nov '17	Dec'17	Jan'18	Feb'18	Mar'18
WP 1 Monitoring and Control System	GE – installations	SAT installations					
	GE – support field trials	Support field trials					
	GE – reporting		Performance report and control scheme data report				
WP 2 Assessment of Response	Flexitricity – demand-side response	Trials for spinning inertia 1					
		Trials for spinning inertia 2					
		Trials for static RoCoF 1					
		Trials for dynamic RoCoF 1					
		Trials for dynamic RoCoF 2					
		Trials for dynamic RoCoF 3					
	Centrica – large scale generation	Large scale generation testing					
	Belectric – solar PV and storage				Solar PV and battery trials		
	Ørsted/Siemens – wind	Wind fleet trials report					
	National Grid – wide-area				SAT	Demonstration and trials	
WP 3 Optimisation	University of Manchester – system studies	Reports on supervisory control					
WP 4 Validation	University of Manchester – validation	Test power network report					
		GB power network report					
		RTDS HiL validation					
	University of Strathclyde – validation	Open loop testing report					
		Closed loop testing report					
WP 5 Dissemination	All partners – dissemination		Website refresh				Dissemination event
				LCNI Conference			
WP 6 Commercial	National Grid – tender			Tender process			
	National Grid – CBA model 1			Cost benefit analysis model 1 – provide upgrades only			
	National Grid – CBA model 2				Cost benefit analysis model 2 – with monitoring and control system		
WP 7 Communications	National Grid – reporting	Report with recommendations regarding implementation of the new service					

Appendix C: Project risk register, risk management and contingency plans

Risk no.	Work streams/ area	Risk description	Cause	Consequence	Risk owner	Likelihood (1-5)	Financial impact (1 - 5)	Reputational impact (1 - 5)	RAG	Escalation route	Action plan	Control opinion
2	General	Partners leave project before completion.	Partner decides to leave the project. Reason could be commercial or operational.	Work is lost or can't start and the project results are less useful or project is delayed.	Project manager	3	2	4	12	Steering Group	Put thorough contracts in place. Procurement processes have considered ongoing size and reliability of partners. Project management is engaging with partners to resolve issues.	Partially effective
3	General	Estimated costs are substantially different to actual costs.	Full scope of work is not understood. Cost estimates are not validated. Project is not managed closely.	Overspend requiring Ofgem change request approval.	Project manager	2	3	4	8	Steering Group	Ensure cost estimates are thorough and realistic and reflect full scope of work. Estimates validated based on tenders and market knowledge. Contingency included.	Partially effective
4	General	Material costs increase.	The cost of materials rises for unforeseen circumstances.	Potential project funding gap. Alternative funding is required or the project scope is reduced.	Project manager	3	2	3	9	Steering Group	Each partner to assess cost of equipment for ongoing basis and provide change requests for additional spend.	Partially effective
5	General	Significant changes to the GB electricity system during the project.	Priorities or strategies for planning and managing the GB system may change.	Solution may no longer be suitable. Assumptions may no longer be accurate or appropriate.	Project manager	5	3	5	25	Steering Group	We will consider future developments and scenarios. We will make sure the solution's usefulness matches planning of system and consider future system/market changes in the Project Closure Report.	Partially effective
6	General	Critical staff leave National Grid or our project partners during project lifecycle.	Usual and unavoidable staff turnover results in key staff leaving National Grid or our project partners.	Progress of the project is delayed. The project team doesn't have the expertise to deliver the project.	Project manager	3	2	3	9	Steering Group	Knowledge of, and responsibility for, project will not be with one person. Make sure there is documentation and guidance to help anyone joining project team. Thorough handover processes to be in place.	Partially effective
7	General	Quality of technology is insufficient: the monitoring and control system and/or equipment installed at response sites.	Least cost option taken ahead of quality and reliability considerations; quality control insufficient at suppliers.	The solution offered is not reliable and commercial opportunities will be reduced. Costs are incurred through delays and replacements.	All partners	5	3	3	15	Project manager	All partners have been assessed based on reputation, track record and responses to NG tender. Make sure that price is not the main criteria. Put quality control procedures in place and follow throughout project.	Partially effective
9	General	Costs of solution over lifetime are high.	Full cost of solution is not considered and/or understood.	The solution's usefulness and commercial opportunities are restricted.	Project manager	4	4	4	16	Steering Group	Full long-term costs of solution have been considered as part of detailed cost benefit analysis calculations.	Partially effective
11	General	Component failure during project.	Equipment will be run in new ways that may cause problems or failures.	The equipment may need to be repaired or replaced. The tests may be delayed.	Belectric, Centrica, GE, Flexitricity	3	3	3	9	Project manager	Thorough checks before tests. Clear understanding of equipment capabilities. Particular stress points identified. Spare parts and repairs lined up. Flexitricity update July 2017: on the first spinning inertia site one of two CHP engines has a damaged camshaft. We are assured that this is not due to the part-load running we are asking it to do. The other remains available to us. The damaged engine will return to service during August. Flexitricity update November 2017: both engines at the first spinning inertia site are now back in service; both engines at second spinning inertia site are also now in service.	Partially effective
12	General	Strategic spares policy.	Spares policy for new technology may not be suitable when all risks are considered.	If suitable spares are not identified and available, the risks of losing the PMU/controller in the network may reduce effectiveness of project.	National Grid	3	3	3	9	Project manager	Contingency plans will be drawn up to include potential alternative monitoring locations that could be used for continued operations if equipment and/or communications fail. Off-the shelf products that are readily replaceable are used. The proposed structure will contain PMUs in each zone that should allow continued supervisory actions with the loss of a device. For the controller, redundancy will be planned for to ensure the loss of the controller is suitably backed-up.	Partially effective
13	General	Maintenance requirements.	Manufacturer recommends intensive and regular maintenance activities that do not fit with project owner's expectations.	Regular intensive maintenance requires additional resource of field staff. This could affect the network operation, reducing power transfer levels and constraint costs.	National Grid	3	3	3	9	Project manager	Seek to work with the manufacturers to understand maintenance requirements and the impact on the design or selection of components. Remote VPN access to controller for remote logging and maintenance, especially for beta release stages.	Partially effective
14	WP7 - Comms	Loss of telecommunications.	Technical fault leads to loss of telecommunications between systems.	Reduced availability and performance.	National Grid	3	3	4	12	Project manager	Design scheme for continued operation or graceful degradation if telecommunications are lost.	Partially effective
15	General	Inefficient operation of MCS.	MCS incorrectly configured, resulting in spurious tripping or excessive amounts of control initiation commands.	Over-response from resources reducing stability; excessive set-point changes in generators reducing asset lifetime.	National Grid	3	3	5	15	Project manager	The scheme will be extensively tested in a laboratory environment before it's used on the network. The system will also be evaluated using recorded measurements from the GB systems allowing tuning and configuration in a safe environment. Academic partners will also provide suitable facilities to test response on generators to reduce risk to assets after deployment.	Partially effective
16	General	High operation and maintenance costs.	Cost for inspection, maintenance, repairs and spares are higher than expected.	Excessive OPEX costs compared to current alternatives.	National Grid	4	3	3	12	Project manager	Maintenance requirements and spares identified during tender evaluation.	Partially effective
17	General	Delays in installing key control scheme components.	Supplier of TO/TSO delays base installation. Delays in implementing control scheme platforms and comms routes to PMUs/controllers/ controllable resources. Co-ordination of National Grid and supplier staff availability.	Delays in key control scheme component will push back the trial, leaving less time for reports, tuning and dissemination.	National Grid	5	2	3	15	Project manager	Select vendor with track record of commercial WAMS installations. Supplier must have experience of deploying in utility environment. Direct support by supplier via VPN for diagnosis. Comprehensive training by supplier for IT personnel in all three partners in IT requirements of WAMS project.	Partially effective
18	General	Communications between devices underperforms.	Communication infrastructure is not fit for purpose.	The existing communication infrastructure may inhibit the speed of response of a control, reducing scheme effectiveness.	National Grid	5	5	4	25	Project manager	Work closely with National Grid and partners to make sure that new comms links not critical to project success. Make sure that the communications infrastructure is well understood and the chosen control scheme can best work with available infrastructure.	Partially effective
19	General	Outage required for commissioning.	Inability to obtain the relevant outages for commissioning.	Possible delays to commissioning programme or cost of outage.	National Grid	5	2	4	20	Project manager	Outages identified and incorporated in scheme requirement document.	Partially effective
20	General	Problems with commissioning procedures.	Commissioning procedures are unclear or untested, being difficult to complete in practice.	Delays in commissioning the project.	National Grid	3	3	3	9	Project manager	Identify and agree all the commissioning procedures with the supplier for the new technology, and the problems that might be encountered.	Partially effective
21	General	Capital costs.	Costs higher than anticipated.	Project budget exceeded.	National Grid	3	3	3	9	Project manager	Proactively manage the finance budget so it stays within original project budget.	Partially effective

Appendix C: Project risk register, risk management and contingency plans cont.

Risk no.	Work streams/ area	Risk description	Cause	Consequence	Risk owner	Likelihood (1-5)	Financial impact (1 - 5)	Reputational impact (1 - 5)	RAG	Escalation route	Action plan	Control opinion
22	Health, Safety and Environmental	Use of new equipment causes a safety incident.	Lack of experience and knowledge about new pieces of equipment.	Health and safety risks caused by lack of experience. Inefficient working could result. Note that controller is low voltage equipment, and actions are taken through existing standard protection and control equipment.	Project manager	2	1	4	8	Steering Group	Specialist tools and training required for maintenance activity. Procedures to be developed and reviewed by all partners' SHES consultants. Controller to go through rigorous testing.	Partially effective
27	WP1 - Control System	Resource interoperability.	Using distributed resources for frequency response is untested in the UK and the availability of resources when called upon is critical. The controller and the individual resources must exchange information so that resources can be called upon when needed.	Lack of comms path or interoperability issues between the controller and the resources could delay initiation of response and make the central control scheme less able to halt frequency excursions.	GE	2	2	2	4	Project manager	Agree common standards and offer a simple IO for all controllable components through standard interface protocols, which will be agreed by all controllable resources. Plan demonstration without critical requirement for communication path to all response providers. Evaluate local control and assess the added benefit that central control brings if made available. Need for different interface protocols to communicate with distributed resources. The concepts of Local Control Units and Central Supervisor were highlighted during project partner meeting 30 April. Specifications Event Detection, Control Platform and Resource Allocation were issued for partner review and comments were addressed. GE will continue engagement with project partners to discuss requirements and concepts for different WP1 Applications. Interface discussions with project partners continue. Interfaces supporting 4-20mA and digital addressed separately.	Effective
30	WP1 - Control System	Controller scalability for roll-out.	The controller will be developed for trial locations using a limited number of sites and corresponding PMU measurements. The control platform's performance may be reduced because of more measurement and resource data with larger-scale roll-out. Another risk is exceeding the computational capacity of the controller with complex algorithms and increased inputs, e.g. more resources to optimise.	Timely roll-out of the scheme could be put at risk, delaying full effectiveness of the scheme and putting the learning from the project into action. The risk for this stage of the project is minimal.	GE	3	4	2	12	Project manager	Laboratory testing will allow scalability testing of the control platform with more inputs than will be used in the trials. This will allow the limits of the control platform to be found and define new ways to overcome these limits. One of the learning outcomes of the project will be how to deploy the control system for larger roll-out, which will minimise the risk of delayed roll-out. Controller development path enables easy porting between hardware platforms - other hardware solutions will be considered if greater performance is needed. GE will continue performance testing/monitoring at different stages throughout the project life-cycle and look into areas for further improvement. 03/11/2017 - intended discussions between GE and NG IS team to discuss infrastructure. No issues expected for PoC.	Partially effective
31	WP1 - Control System	Additional testing and tuning.	The controller may require additional tests and fine tuning based on real system measurements from the UK network to ensure robust operation. Data will need to be gathered over enough time to determine the control scheme performance.	The selected control scheme will be unable to effectively deploy resources to arrest a frequency excursion.	National Grid	5	3	3	15	Project manager	Information gathered from VISOR can provide an extended period of system measurements. This data can be replayed in the laboratory environment to test the control scheme with real measurements from the UK system. This will validate the behaviour and allow a longer capture period for sufficient disturbances.	Partially effective
36	WP2.1 - DSR	DSR trials prove unfeasible.	Complex technical interaction with existing commercial site processes.	Ability of DSR to deliver EFCC not proven.	Flexitricity	2	4	4	8	Project manager	Pursue three separate technical approaches to spread risk (RoCoF, real inertia, simulated inertia). Investigate technical feasibility for higher risk technical approaches (especially simulated inertia) before trials. Flexitricity update Nov 2017: we have completed commissioning in two of three strands and are progressing with the third.	Partially effective
37	WP2.1 - DSR	Delay between detection and action too long for distributed resources including DSR.	Long signalling chain including communicating with remote sites.	Cannot dispatch some resources fast enough.	Flexitricity	2	3	3	6	Project manager	Include at least one fast-acting technical approach (RoCoF) for DSR, to compensate for other possible signalling delays.	Partially effective
38	WP2.1 - DSR	Cost of DSR too high for large-scale roll-out.	Controls modifications (especially RoCoF and simulated inertia), spark spread (especially real inertia).	Project does not result in economic source of EFCC from DSR.	Flexitricity	3	3	4	12	Project manager	Pursue three separate technical approaches to spread risk (RoCoF, real inertia, simulated inertia).	Partially effective
39	WP2.1 - DSR	DSR deployment lead time too long.	Normal delays in dealing with industrial and commercial energy users.	Unable to operate long enough trial; some customers are already too late for trial.	Flexitricity	3	3	3	9	Project manager	Start EP recruitment during phase 1; show flexibility on trial dates and durations. Flexitricity update July 2017: the local controller has been difficult to configure and has not been behaving consistently during tests. The local controller needs to operate consistently before being sent to the static RoCoF site, and before releasing the data logger to the second spinning inertia site. Flexitricity update Nov 2017: while the window for trials has reduced, it now seems likely that all sites will be commissioned with enough time to gather adequate data. One site remains at risk, as it has suffered excessive exposure to non-RoCoF frequency trips.	Partially effective

Appendix C: Project risk register, risk management and contingency plans cont.

Risk no.	Work streams/ area	Risk description	Cause	Consequence	Risk owner	Likelihood (1-5)	Financial impact (1 - 5)	Reputational impact (1 - 5)	RAG	Escalation route	Action plan	Control opinion
40	WP2.2 - Large-Scale Generation	CCGT operators struggle to get relevant technical input from OEM.	Lack of communication or timely response from OEM.	The project is delayed.	Centrica	1	2	2	2	Project manager	Draw up 'heads of terms' with OEM. Pay OEM (from funding) for relevant technical input.	Partially effective
41	WP2.3 - PV Power Plant	Bad weather (low irradiation).	Poor weather conditions will mean that trials cannot take place.	Insufficient test conditions will lead to delays in testing.	Belectric	3	2	2	6	Project manager	Plan tests accordingly.	Partially Effective
44	WP3 - Optimisation	Detailed models of the various technology types are not made available to academic partners for system studies.	Poor communication and project management. Possible restrictions on data.	Without detailed technology models, any optimised control scheme will be based on generic assumptions about technology capabilities, which may not be accurate. This means that true and simulated performances will not align.	Universities	4	2	2	8	Project manager	Detailed models of Doubly Fed Induction Generator (DFIG), Combined Cycle Gas Turbine (CCGT), PV and Battery storage models are developed in PowerFactory for system studies and Demand Side Response (DSR) is on-going.	Partially Effective
46	WP5 - Dissemination	Knowledge gained from the project is not shared properly with industry and other interested parties.	Lack of resources dedicated to dissemination. Failure to deliver events, website, etc.	A major benefit of, and reason for, the project is lost. Performance of solution and lessons learned are not shared.	Project manager	1	3	5	5	Steering Group	Make sure knowledge sharing is a priority. Establish formal processes to disseminate results, reports, etc. Use working group, internet, academic partners to facilitate sharing.	Partially Effective
47	WP6 - Commercial	Market for EFCC not taken up by possible resource providers.	Knowledge not disseminated, meaning providers unable to prepare. Commercial arrangements not attractive.	The successful roll-out of the solution will be delayed.	Project manager	4	4	4	16	Steering Group	Make sure knowledge is shared. Establish clear communication channels with interested parties. Develop commercial terms thoroughly before roll-out.	Partially Effective
48	WP1 - Control System	Demonstration partner fails to install and configure demonstration set-up on time for SAT.	Challenges with installation and configuration or lack of understanding/training.	Demonstration is delayed, which is likely to affect other activities.	GE, Centrica, Flexitricity, National Grid	3	1	1	3	Project manager	GE will provide PMU/MCS training during Demonstration #1 timeframe (combined with FAT). GE support effort during installation has been quantified for the different demonstration phases. Scope of works, functional design specification and system design specification will be produced as input to partner installation activities. Demonstration #1 has been successfully completed. Deployments at UoM, PNDC and Belectric have been completed successfully. 03/11/2017 - GE will provide additional support during SAT installation and technical field trials; onsite visits to Flexitricity and PNDC offices were organised to support project partners. Flexitricity Update Nov 2017: on-site installation carried out and SAT completed on 26/10/17.	Effective
56	WP2.5 - Wind	EFCC project needs to agree with DONG and Siemens and associated Joint Venture partners for the use of windfarm (test to be conducted on 6 MW turbines without deloading).	Delay in agreeing use of windfarm.	Delays to work package and overall project outcomes.	National Grid	5	3	3	15	Project manager	Agree schedule of tests and activities early in the negotiation process and start contractual discussions in parallel. Contractual discussions ongoing, outstanding action relating to liability indemnity (requires senior NG approval). Alternative windfarm site provided by DONG (Burbo Bank) which will assess how fast and for how long wind farm can provide frequency response.	Partially effective
61	WP2.5 - Wind	Revised timeline for wind workpack does not co-ordinate with the other workpacks.	Delays caused by the length of time to sign new partner contracts and unforeseen model data validation issues.	Wind test findings not being available in time for meaningful inclusion in the project conclusions and recommendations.	Project manager	2	3	4	8	Steering Group	Confirmation from DONG that trials at Burbo Bank will start on 22/6/17 and align with other resource provider trial dates.	Partially effective
62	WP3 - Optimisation	Revised timeline for University of Manchester affects project's work deliverables.	University of Manchester deliverables slipping due to delays in project recruitment and acquiring the appropriate tools for the systems studies.	Timeline for work deliverables compromised.	Project manager	3	3	4	12	Steering Group	Revised project timeline agreed with University of Manchester, with associated project dependencies identified and managed.	Partially effective
63	General	General back loading of deliverables in the project.	Slippage against baseline for deliverables.	Compromising scope and quality of deliverables.	Project manager	5	4	5	25	Steering Group	NGET and partners have monthly review of planned deliverables, identifying any issues with delivery, investigating alternatives and escalating to Steering Group.	Partially effective
64	General	Hand-offs between partners are delayed.	Hand-offs are not clear in the plan or not proactively managed to ensure the planned timeline is kept.	Delays compromising other work deliverables.	Project manager	4	3	4	16	Steering Group	Dependency management planning included as standing agenda item at Steering Group meetings, where handoffs, with dates, are confirmed or delivery issues are discussed and solutions identified.	Partially effective
65	WP4 - Validation	System testing is delayed.	1. Additional trial equipment requirements identified, which are not immediately available. 2. Identifying an issue in MCS and communication with GE to receive a new frame-work of AFBs regarding unexpected behaviour might also cause a delay in HiL-testing.	Delay in testing phase, knocking on to delaying the general project timeline.	University of Manchester	4	3	3	12	Steering Group	1. Additional trial equipment (such as GPS Grandmaster clock and Managed Ethernet switch) are delivered with a three month delay. 2. Proper support from GE to address unexpected behaviour of PhasorController and new update of AFBs when necessary. First report for HiL testing based on standard 2-area test system model for assessment of a range of system cases and operational conditions to test the functionality of developed AFB is submitted to NG. Second report for testing the entire MCS will be submitted and proper support from GE is required to solve unexpected behaviour of MCS.	Partially effective
66	WP2 - All	Test programme and schedule not clearly defined.	Test programme format not clearly defined, impacting scheduling of commercial trials.	Delays in starting the test plan and quality of test outputs.	Project manager	4	3	4	16	Steering Group	Escalation to Steering Group for discussion and resolution. UoM have developed a test template that has been circulated to all other partners for completion.	Partially effective
67	WP2.2 - Large-Scale Generation	Trial timeline delayed due to potentially volatile market prices.	Recent high market prices creates reluctance to carry out non-essential work on plant.	Centrica delays testing programme.	Centrica	1	3	3	3	Project manager	Centrica mitigation is that work is low risk and may be delayed a week or two if prices are exceptionally high at the time of planned works.	Effective

Appendix C: Project risk register, risk management and contingency plans cont.

Risk no.	Work streams/ area	Risk description	Cause	Consequence	Risk owner	Likelihood (1-5)	Financial impact (1 - 5)	Reputational impact (1 - 5)	RAG	Escalation route	Action plan	Control opinion
68	WP7 - Comms	Delay in delivering the workpack WP7.	Understanding the nature of the WP deliverables and unable to access specialist resourcing skills.	Work package is not delivered on time, undermining success of project.	Project manager	3	3	5	15	National Grid	Recruit specialist resource and draw upon existing expertise within NGET. NG IS team identified who will undertake assessment, initial meeting with universities to discuss EFCC infrastructure taken place. Work is ongoing.	Partially Effective
69	WP6 - Commercial	Delay in delivering the commercial workpack.	Understanding the nature of the WP deliverables and unable to access specialist resourcing skills.	Work package is not delivered on time, undermining success of project.	Project manager	5	3	5	25	National Grid	Recruited specialist resource who will draw on existing expertise within NGET. Further recruitment ongoing. Will align with FRSO flexibility work stream (product simplification consultation) - resource field trials to input into consultation process. Develop further commercial work packages with EFCC infrastructure.	Partially Effective
70	WP2.2 - Large-Scale Generation	Centrica unable to take part in project and deliver WP2.2.	Centrica has sold CCGT which is used for trials.	Centrica do not complete trials, putting WP2.2 at risk of non-delivery.	Centrica	1	3	3	3	Steering Group	EPH have said several times that they want to continue on the project. Contractual details with EPH to be confirmed. Preferred option is EFCC contract with EPH South Humber Bank continues and EPH sub-contract with Centrica to continue to manage project. Terms for this have been drawn up but not yet signed.	Partially Effective
71	WP2	Non-delivery of a meaningful NG demonstration (simulation and/or network).	Lack of clarity in original submission and difficulty in differentiating NG demonstration from other partners' demonstrations.	Lack of evidence of how the system would operate in a real operational environment.	Project manager	4	1	5	20	National Grid	1. NG technical resource has now been engaged to dedicate time and effort to this risk. 2. We shall approach other partners for support as required 3. Plan to be developed and implemented.	Partially Effective
73	WP2.3 - PV Power Plant	Insufficient time left to complete trials.	Equipment failure and delays to the installation of other components (batteries).	Insufficient data to draw any meaningful conclusions, to feed into commercial work package. Delays in project milestones (SDRC).	Belectric	5	3	4	20	Steering Group	Engage with Belectric to develop revised project timeline which mitigates against project risks.	Partially Effective
74	WP2.1 - DSR	Delays to dynamic RoCoF trails.	Insufficient operational hours at Dynamic RoCoF sites.	Insufficient data to draw any meaningful conclusions, to feed into commercial work package. Delays in project milestones (SDRC).	Flexitricity	3	3	3	9	Steering Group	Additional resources are required to assist with the fast tracking of the trials. Flexitricity update November 2017: additional resource applied; three sites now progressing well; go-live of first site expected mid-Nov.	Effective
75	WP4 - Validation	Delay in finishing all the test activities and requirement for extra staff and PNDC facility time.	Issues were identified during tests and need extra time for GE to fix and further tests are required to verify the new versions of the system.	Delay in overall project schedule.	Universities	4	2	3	12	Project manager	Close communication with GE has been maintained to ensure the issues are resolved as soon as possible and the impact to the test schedule is minimised.	Partially effective
76	WP3 - Optimisation	UoM workload is too broad to demonstrate application system outcomes from EFCC.	Scope of WP3 was unclear.	Project closure report not having sufficient information on effects of EFCC in the future.	University of Manchester, National Grid	4	1	4	16	Project manager	NG to clarify scope then prioritise with UoM.	Partially effective
77	WP7 - Comms	Existing telecommunications network and PMUs unable to support the developed MCS functionality for BaU roll out.	Incompatible communications protocols used plus differing ETO and SO priorities for the same fault recorder equipment with PMU functionality enabled.	Fault recorders and dynamic monitoring equipment process frequency data for system monitoring purposes. The project is unable to achieve the targeted speed of response times.	Project manager	5	4	4	20	National Grid	Feed outcomes of the NG demonstration into WP7 impact assessment.	Partially effective
78	WP2 - NG Demonstration	The data input into the MCS for the NG demonstration is likely to be complicated, manual and time intensive.	The MCS developed to date is only a prototype and is therefore not as user friendly as it could be!	The NG demonstration could be difficult to implement and very time consuming leading to potential delays.	Charlotte Grant and Nick Martin	5	3	3	15	Project manager	Procure the MCS early for evaluation and incorporation. Develop an approach to the NG demonstration that is as automated and efficient as possible (i.e. requires the least amount of manual data entry).	Partially effective
79	WP4 - Validation	Delay in completing stage 2 physical testing due to fault in MG set. Replacement part has a 2-3 week lead time.	The MG set tachometer has developed a fault which prevents the MG set from running.	Delays in overall test completion schedule.	University of Strathclyde	5	1	1	5	Project manager	Multiple replacement part suppliers have been contacted to determine if the lead times can be reduced. Wide-area testing (stage 2) will be conducted using RTDS simulation in order to identify any wide-area control issues that can be resolved with GE ahead of physical testing. Communication tests will be conducted meanwhile to minimise the overall delay caused by the MG set fault. Internal discussion will be held to prioritise the EFCC tests at PNDC once the MG set is back online.	Partially effective
80	WP2.3 - PV Power Plant	Lack of contract with new solar farm owners means that the solar trials do not take place.	Belectric have sold the solar farm to new owners who are not contracted with NG to carry out EFCC trials.	Project does not meet one of original aims.	Belectric	5	4	4	20	Project manager	Belectric negotiating with solar farm owners for trial participation. Belectric and NG to agree financial compensation to new solar farm owners.	Partially effective

Closed risks

Risk no.	Work streams/ area	Risk description	Cause	Consequence	Risk owner	Likelihood (1-5)	Financial impact (1 - 5)	Reputational impact (1 - 5)	RAG	Escalation route	Action plan	Control opinion
23	WP1 - Control System	Technology partner fails to deliver suitable product on time.	Problems with design and build.	Project is delayed.	GE	3	2	2	6	Project Manager	Contracts to be put in place to penalise delays. Clear specification requirements in place. Development of technology to be closely managed to identify and resolve potential problems. Hardware platform delivered by GE unit in Massy/France. Product commercially available by summer 2015. Assessment of technical suitability completed with positive result. GE management support secured during project approval and project review meetings. A formal collaboration framework with GE internal supplier currently being put in place. Product considered suitable for C37.118, IEC 61850, IEC 60780-5-104, Modbus and Digitals (up to six digitals). Suitability for 4-20mA and Digital captured separately in Risk Register. GE demonstrations of hardware functionality successful demonstrated during Training and Demonstration #1 FAT (Oct 2016) and demonstrations at the University of Manchester, PNDC and Belectric (Feb-Mar 2017). 03/10/2017 - sufficient demonstration of technology readiness to increase confidence.	Effective
24	WP1 - Control System	Technical specification is not clear enough to deliver the technology or contains errors.	Requirements not fully understood. Quality control processes insufficient.	The technology developed may not match requirements or be suitable.	GE	2	2	2	4	Project Manager	Care to be taken over technical specification, with input from all relevant partners. Review process and then regular communication with GE and other partners to identify and resolve issues quickly. Specifications Event Detection and Control Platform were issued for partner review. Review comments assessed/discussed during project meetings. Resource allocation and optimisation split into two parts, i.e. functional specification and design report. Formal QA with project partners done. Presentations concepts Event Detection and Resource Allocation during face-to-face Steering Committee meeting. Dedicated workshops for optimisation with NG and UoM. GE demonstrations of application functionality successfully demonstrated during Training and Demonstration #1 FAT (Oct 2016) and demonstrations at the University of Manchester, PNDC and Belectric (Feb-Mar 2017).	Effective
25	WP1 - Control System	Flexible embedded real-time controller not commercially available.	A controller with the flexibility to employ the required algorithm is not currently available and will require significant development. Resources must be in place for a timely start to the platform development.	Delays in sourcing suitable resources may extend the development period and delay deployment and trials.	GE	1	1	2	2	Project Manager	Source suitable development resources before project begins so it can start in good time. Two embedded software developers have been working on the project since January 2015. Hardware platform commercially available from summer 2015 onwards. The project team has two units available for development and testing. Bi-weekly meetings with TPSA Massy team to ensure timely delivery of new TPSA boards, BSP upgrades, knowledge transfer and documentation. Tasks, deliverables and issues recorded/tracked in MS Project. 4-20mA currently not in TPSA Product Roadmap. Digital capabilities limited in terms of board hardware setup and number of digitals available. Proposal to implement Modbus to 4-20mA/digital convertors and to discuss option product development TPSA in terms of 4-20mA and digital interfaces. GE demonstrations of flexible real-time controller functionality successful during Training and Demonstration#1 FAT (Oct 2016) and demonstrations at the University of Manchester, PNDC and Belectric (Feb-Mar 2017). 03/10/2017 - controller units delivered.	Effective
26	WP1 - Control System	Event detection and response algorithms not available on embedded real-time controller.	The controller will use custom functions that are not currently available on the embedded control platform to determine the appropriate reaction. These functions must be developed and tested before deployment. New control approaches need to be developed.	Extension required for the development period, which delays all consecutive elements of the project.	GE	2	1	2	4	Project Manager	Staged approach to application development with simple initial target in first year. Allow sufficient resources for all stages of algorithm development so there's enough effort in the project's early stages to avoid delays. This will also allow for resources to make any modifications that come out of the early testing. The project has aimed for early/staged end-to-end testing/demonstration for phasor data concentrator, regional aggregator, system aggregator and event detection. This agile approach has validated/confirmed system architecture, development strategies and design concepts at early stages and allows for any fine-tuning. Project partners receive regular progress updates and confidence level. Event detection and response algorithms have been successfully tested and demonstrated. Applications have been handed over to academic and commercial partners for simulation testing and technology field trials. Control Platform and Applications are taken into the next phase of the project, i.e. demonstration phase. 03/10/2017 - validation exercise conducted by academic partners has provided sufficient confidence level.	Effective

Closed risks cont.

Risk no.	Work streams/ area	Risk description	Cause	Consequence	Risk owner	Likelihood (1-5)	Financial impact (1 - 5)	Reputational impact (1 - 5)	RAG	Escalation route	Action plan	Control opinion
28	WP1 - Control System	Resource flexibility.	Resources do not offer enough flexibility for control under proposed control scheme. They either offer a response that is difficult to quantify or one that is difficult to tune.	May require redesign of the control scheme adding delays to deployment.	GE	3	2	2	6	Project Manager	Collaborate closely with project partners through all stages to ensure that control scheme is designed according to limits of operation of various resource types. Especially, collaboration between GE and academic partners on optimisation. 03/10/2017 - validation exercise conducted by academic partners has provided sufficient confidence.	Effective
29	WP1 - Control System	Control scheme trial outcome.	Due to the innovative nature of the project, the selected control scheme's trials may yield negative results, or introduce additional problems.	The selected control scheme will be unable to effectively deploy resources to arrest a frequency excursion.	GE	3	2	2	6	Project Manager	The risk is mitigated by using candidate solutions based on wide-area control, local-control and a hybrid approach using both. If there are problems with one candidate solution, other solutions will be available. 03/10/2017 - validation exercise conducted by academic partners has provided sufficient confidence.	Effective
32	WP1 - Control System	Data quality.	Inadequate data quality from PMUs due to problems with communications infrastructure, incompatible PMUs or from existing PMUs where experience has shown poor quality data.	Controller application value and performance reduced.	GE	4	1	1	4	Project Manager	Require data proof prior to installations. Use PMUs that have evidence of acceptable practical performance, and standards compliance where possible. Applications to be robust to data packet loss. Review of data quality issues and resolution/improvement to be carried out. EFCC algorithms have been designed/developed to deal with data quality issues. Concepts such as confidence level and weighting have been introduced to include additional meta-data and logic to deal with data quality issues. 03/11/2017 - data quality is integral part of concepts/exception handling. UoS validation has focused on these issues, with satisfactory results during testing. UoS test report should confirm robustness/operational readiness of SFC scheme/functionality.	Effective
33	WP1 - Control System	RoCoF trip risk.	Controllable resources that arrest frequency excursion may be conflicted by own loss of mains RoCoF settings and trip. Also, risk of fast response rolling off at df/dt=0 when it should be sustained.	Loss of effectiveness of resources - unavailable for frequency support or prematurely returned to normal service.	GE	4	1	2	8	Project Manager	For trial purposes, RoCoF should be low enough to avoid conflicts of LoM detection, but the problem will be assessed for future roll-out. Project will provide learning outcome that can inform future grid codes. Also, co-ordination of control to ensure smooth transitions between stages of response. 03/11/2017 - considered under control.	Effective
34	WP2.1 - DSR	Flexitricity is unable to provide participants for planned trials.	Timing, risk and commercial terms makes it difficult to recruit DSR participants.	Trials are limited or unable to take place. The suitability and performance of the technology is not established.	Flexitricity	1	3	3	3	Project manager	Participants provided for planned trials. Residual risk is that sites withdraw or we can't find companies to sign-up for the dynamic RoCoF trials. 05/09/2017 - Flexitricity provided trail partners.	Effective
45	WP4 - Validation	Unable to model the UK network with sufficient detail using the RTDS facilities in order to thoroughly validate proposed control solutions.	Lack of required data. Lack of expertise on project.	Wide scale rollout may be severely impacted by issues not flagged during the validation phase.	Universities	2	3	3	6	Project manager	2-area test system network and reduced substation model of 36-zone GB system have been simulated and modelled in RTDS for HiL-testing of GE-MCS. Development of appropriate RTDS models was essential for the RTDS HiL-testing. These models are extracted from PowerFactory models and they have been developed in RTDS.	Effective
49	WP1 - Control System	PMU/MCS hardware delivery.	Late delivery of PMUs and/or MCS controllers.	Demonstration is delayed, which is likely to affect other activities.	GE	2	1	1	2	Project manager	Engage early with suppliers and project stakeholders to make sure delivery and installation are on schedule. PMU hardware delivered to site. Controller hardware available for configuration in Edinburgh. Hardware delivered to UoM, PNDC and Belectric sites. 03/11/2017 - TPCOM hardware delivered/available.	Effective
50	WP1 - Control System	The number of interface protocols impacts the development and testing effort.	Project partners decide on multiple interfaces and/or different messaging protocols.	Extra design, development and testing effort required, which would affect project delivery timelines.	GE	2	1	2	4	Project manager	Interfaces developed and tested. Development and testing has been impacted due to extra scope and complexity. Milestone Testing Control Platform missed. Interim report issued and control platform testing extended by one month. Final report issued to project partners end of Sept 2016. Overall timelines respected and Demonstration Phase is as planned. 03/11/2017 - interfaces delivered. Interfaces tested with UoM, UoS, Belectric and Flexitricity. Interfaces ready for testing with Centrica.	Effective
55	WP1 - Control System	Number of PhasorController applications.	Concept design frequency control has identified potential for the following controller applications: - Local PhasorController for system aggregation, fault detection, event detection and resource allocation. - Regional controller for regional aggregation and fault detection. - Central PhasorController for management and distribution of configuration data (settings, thresholds, parameters).	Depending on the demonstration schemes envisioned, more hardware might be needed. Extra effort might be required to develop, configure and test the extra controller units.	GE	5	2	2	10	Project manager	Number of applications and control platform capabilities have been defined and verified. Demonstration #1 has proven working concept. Successful SATs at UoM, PNDC and Belectric. Academic testing ongoing. 03/11/2017 - extra hardware was ordered for NG Demonstration.	Effective
58	WP1 - Control System	4-20mA interface.	4-20mA currently not part of TPSA product roadmap due to other priorities.	Full 4-20mA interface not ready for demonstration testing.	GE	2	3	3	6	Project manager	Communicate proposal for inclusion of Advantech ADAM 6024 Convertor Modbus to 4-20mA.Successfully tested.	Effective
59	WP1 - Control System	Digital interface not ready for testing.	Capabilities digital interface limited. Alternative hardware solution required if more than six digitals are needed. Product enhancement required within TPSA product roadmap.	Full digital interface not ready for demonstration testing if more than six digitals needed.	GE	2	3	3	6	Project manager	Communicate proposal for inclusion of Advantech ADAM 6024 Convertor Modbus to Digital for setups requiring more than six digitals. Successfully tested.	Effective

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