Issue 05

Enhanced Frequency Control Capability (EFCC)

Progress report: January to June 2017

Contents

Executive summary

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

This changing energy landscape leads to system challenges that are explained in National Grid’s System Operability Framework (SOF)*. One of the 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 consequences of faults on the electricity network.

National Grid is working with industry and academia on the Enhanced Frequency Control Capability (EFCC) project. This aims to provide greater clarity on the application and benefits of 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.

* http://www.nationalgrid.com/SOF

Summary of progress: January to June 2017

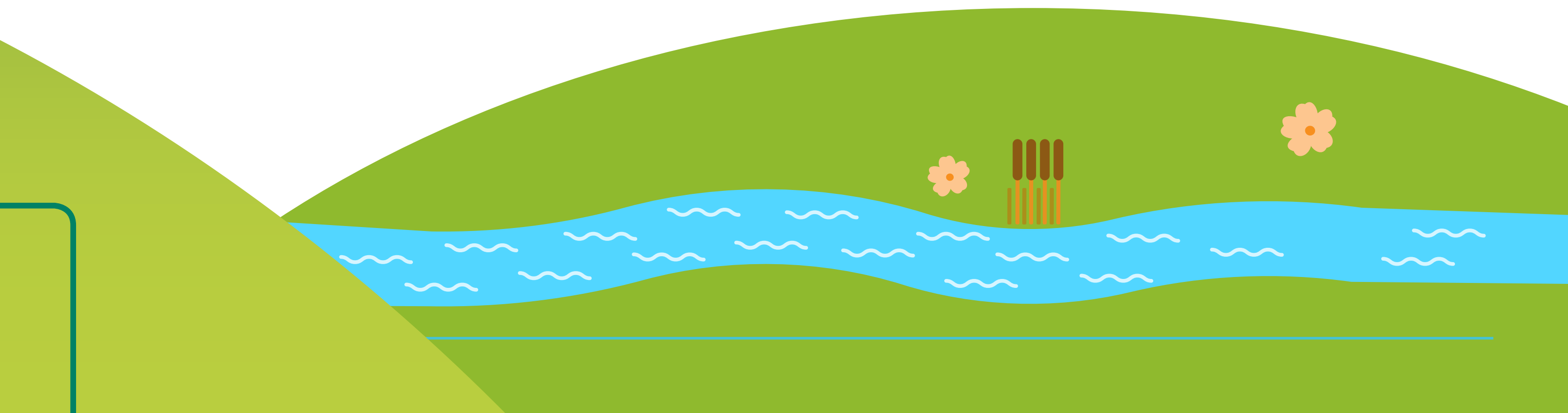
During this reporting period we focused on demonstrating the GE Grid Solutions monitoring and control system (MCS) and on handing it over to project partners for validation and field trials. Site acceptance tests (SATs) were successfully completed at the University of Manchester, the University of Strathclyde and at the solar PV plant owned and operated by Belectric. Site acceptance tests for all remaining project partners will continue throughout the next reporting period, when the validation and demonstration of rapid frequency control will begin in earnest.

We are working with DONG Energy and Siemens to agree an approach to potential wind turbine trials. The aim will be to demonstrate a windfarm’s ability to provide fast frequency response. A stage-one contract has been signed for trials to take place on test turbines and this work has started. We are discussing a stage-two contract for trials on a fully operational, commercial windfarm. One of the main outstanding challenges in finalising this stage-two contract is the sharing of liabilities during the work.

Through continuing engagement with industrial and commercial electricity customers, Flexitricity now has all the necessary contracts in place across the three DSR categories targeted by the project: static Rate of Change of Frequency (RoCoF), real inertia and simulated inertia/dynamic RoCoF. Preparation and installation work is now taking place.

A highlight of this reporting period was the hugely successful second knowledge dissemination and stakeholder engagement event at the Technology Innovation Centre at the University of Strathclyde on 14 March. Approximately 120 stakeholders from across the industry attended and the entire project team delivered a day of interactive sessions sharing their knowledge and insights.

The project team is now focused on the next phase of the project. This phase will include validating and demonstrating rapid frequency control. We will develop a commercial framework to encourage the widest participation in a new market for fast frequency response. We will also assess the data communications infrastructure needed to support the monitoring and control system and determine how best to integrate this into business as usual activities.



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) and a reduction in system inertia is known to increase the risk of rapid changes to system frequency and the threat of faults or blackout. This in turn will mean we have to deliver more frequency response more quickly, to keep the transmission network stable.

Through our Enhanced Frequency Control Capability (EFCC) project we are working with industry and academia to clarify the application and benefits of innovative ways to control frequency in low-inertia transmission systems. The project aims to explore how technologies like wind, solar PV, demand-side response (DSR) and combined cycle gas turbines (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, the EFCC project aims to open the door to more frequency response being provided by newer, more sustainable energy solutions. It 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 generated by 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 **www2.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 fifth progress report and covers the period of January to June 2017.

Major project deliverables and issues during the reporting period include the following.

Site acceptance testing – the main focus was on demonstrating the GE Grid Solutions monitoring and control system and handing it over to other project partners for validation and field trials. Site acceptance tests have been successfully completed at the University of Manchester, the University of Strathclyde and the solar PV plant owned and operated by Belectric. Further site acceptance tests for the remaining project partners will continue throughout the next reporting period.

Knowledge dissemination event – in March the project hosted a second hugely successful knowledge dissemination and stakeholder engagement event that attracted around 120 stakeholders from across the industry. The entire project team delivered a day of interactive sessions designed to share their knowledge and insights.

Work Package 2.5: Wind – we reported previously that the project had yet to confirm the involvement of a commercially operational windfarm. Throughout this reporting period we have continued to engage with DONG Energy and Siemens in order to draw up an outline schedule for testing windfarms' capabilities to provide rapid frequency response and the associated costs of doing so.

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 meetings to discuss project progress, identify and manage risks, and agree actions. We are holding more individual project partner engagement meetings too.

There have been no changes to the steering committee hierarchy within this reporting period.

Project progress against SDRC milestones

Progress against our successful delivery reward criteria (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: January to June 2017

Description	Due Date	Status
Agreements in place with DSR customers for participation in EFCC trials	30 June 2016*	Achieved 30 April 2017
Monitoring and control system developed successfully: Application development: Revision completed	31 March 2017	Achieved 24 March 2017
EFCC knowledge dissemination and stakeholder engagement event	31 March 2017	Achieved 14 March 2017

* For further information please refer to our December 2016 EFCC progress report.

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 – most of the reports that are produced throughout the lifetime of the project are part of the intellectual property that's being developed.

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

Table 2
Knowledge-sharing events: January to June 2017

Event / Publication	Date	Organisation	Contribution
Energy Storage Network	January 2017	Flexitricity	Presentation of inertia response and other opportunities to energy storage developers
Cornwall Energy Smart Flexible Energy System	February 2017	Flexitricity	Panel session covering role of frequency response in system balancing
REA Energy Storage	February 2017	Flexitricity	Presentation of inertia response and other opportunities to energy storage developers
IET, Manchester, UK International Conference on AC and DC Power Transmission	February 2017	University of Strathclyde	Studies of dynamic interactions in hybrid AC-DC grids under different fault conditions using real-time digital simulation
NIC EFCC Knowledge Dissemination Event	March 2017	All	Full project knowledge dissemination and stakeholder engagement event (for further information see below)
Data Centre World	March 2017	Flexitricity	Static RoCoF opportunities for datacentres
Alexa Capital	March 2017	Flexitricity	Explanation of EFCC opportunities at a round-table investment forum
IEEE PES, Istanbul, Turkey 5th International Istanbul Smart Grid and Cities Congress	April 2017	University of Manchester and University of Strathclyde	Smart integrated adaptive centralised controller for islanded micro-grids under minimised load shedding
CIGRE, Saint-Petersburg, Russia Relay Protection and Automation for Electric Power Systems	April 2017	University of Manchester	A centralised under frequency load-shedding controller based on state estimator for micro-grid applications
IEEE PES, Torino, Italy Innovative Smart Grid Technologies (ISGT) Conference	September 2017 (paper pre-selected in this reporting period)	University of Strathclyde	Application of a MW scale motor generator set to establish power hardware in the loop capability

Knowledge dissemination event

On 14 March the project hosted a hugely successful second knowledge dissemination and stakeholder engagement event at the Technology Innovation Centre at the University of Strathclyde.

The entire project team delivered a day of interactive sessions designed to share their knowledge and insights. Sessions included GE Grid Solutions presenting EFCC concepts and demonstrating PhasorController capabilities; and the Universities of Manchester and Strathclyde presenting their latest simulation analysis and their real-time digital simulator (RTDS) capabilities.

The University of Strathclyde had also developed a simulation-based tool that allows users to visualise the impact of various levels and types of EFCC response on power system frequency following disturbances. This open-source graphical software tool, called the 'System Frequency Response Demonstrator', is capable of demonstrating a power system's frequency behaviour during disturbances under different system operating conditions (e.g. demand levels, inertia values etc.) with and without various user-configurable levels and types of EFCC response. The tool is available to download from: http://dx.doi.org/10.15129/caf3e32e-c07d-4366-867f-89296117cc3d.

Around 120 stakeholders from across the industry attended the event, including generator representatives, financiers, academics and consultants. With so many experts assembled in one place, the project team worked hard to make the most of that opportunity by encouraging feedback throughout the day. For further information, please visit our project website at www2.nationalgrid.com/efcc.

Project manager's report cont.

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: July to December 2017

Work Package	Description	Partner	Comments	Status	Timescale
1	Monitoring and Control Scheme	GE Grid Solutions Flexitricity	Demonstration Phase 4: installation, configuration and SAT of phasor measurement units (PMUs) and control hardware for demand-side response field trials	Green	Jul 2017 to Aug 2017
1	Monitoring and Control Scheme	GE Grid Solutions Centrica	Demonstration Phase 4: installation, configuration and SAT of PMUs and control hardware for large-scale-generation field trials	Green	Jul 2017 to Aug 2017
1	Monitoring and Control Scheme	GE Grid Solutions National Grid	Demonstration Phase 4: installation, configuration and SAT of PMUs and control hardware for National Grid testing	Green	Jul 2017 to Aug 2017
1	Monitoring and Control Scheme	GE Grid Solutions	Deliver control platform revision report outlining revisions to the MCS control platform	Green	Jul 2017
1	Monitoring and Control Scheme	GE Grid Solutions	Deliver performance report outlining review of the field trials associated with the different partners and recommendations for control parameter tuning	Green	Jul 2017 to Dec 2017
2.1	Demand-Side Response	Flexitricity	Prepare for and start demand-side response field trials	Green	Jul 2017 to Nov 2017
2.2	Large-Scale Generation	Centrica	Prepare for and start large-scale-generation field trials	Green	Jul 2017 to Nov 2017
2.3	Solar PV Power Plant	Belectric	Prepare for and start solar PV power plant field trials	Green	Jul 2017 to Oct 2017
2.5	Wind	DONG Energy Siemens	Prepare for and start wind field trials	Green	Jul 2017 to Nov 2017
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*1	Jul 2017 to Nov 2017
4	Validation	Universities of Manchester and Strathclyde	Implement monitoring and control system for Hardware in the Loop (HiL) and Power Networks Demonstration Centre (PNDC) testing and start validating GE Grid Solutions' developed system	Amber*1	Jul 2017 to Nov 2017
6	Commercial	National Grid	Start to assess economic value of new rapid frequency service	Amber*2	Jul 2017 to Dec 2017
7	Communications	National Grid	Start evaluating the communication infrastructure requirements and assess the current technical capabilities of the system. Coordinate installation of additional PMUs at National Grid substations to increase wide-area monitoring (WAMs) capability	Amber*2	Jul 2017 to Jan 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

*1 These activities are amber because of the delay in recruiting research assistants at the University of Manchester, as previously reported. The affected work packages continue to be reviewed to make sure that the necessary study analysis is completed.
*2 These activities are amber because we are still awaiting the necessary commercial and technical resource.

Project manager's report cont.

Business case update
Work Package 2.4: Battery Storage

It has previously been reported that the project would not be awarded the requested funding for a new battery storage unit for combined solar PV and battery storage trials. However, the project team believes that battery storage can still play a significant role in ensuring system reliability. Therefore Network Innovation Allowance (NIA) funding has been sought, and subsequently approved, to cover the costs of leasing the Belectric battery storage facility for the duration of the EFCC trials.

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 new options they could bring to the electricity sector.

Project budget

Project expenditure is within the budget defined by the Project Direction*.

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.

* https://www.ofgem.gov.uk/sites/default/files/docs/2015/01/enic_project_direction_efcc_final_0.pdf

Progress against budget

Table 4 details the project expenditure to date (as of 31 May 2017) and highlights any variances against the budget.

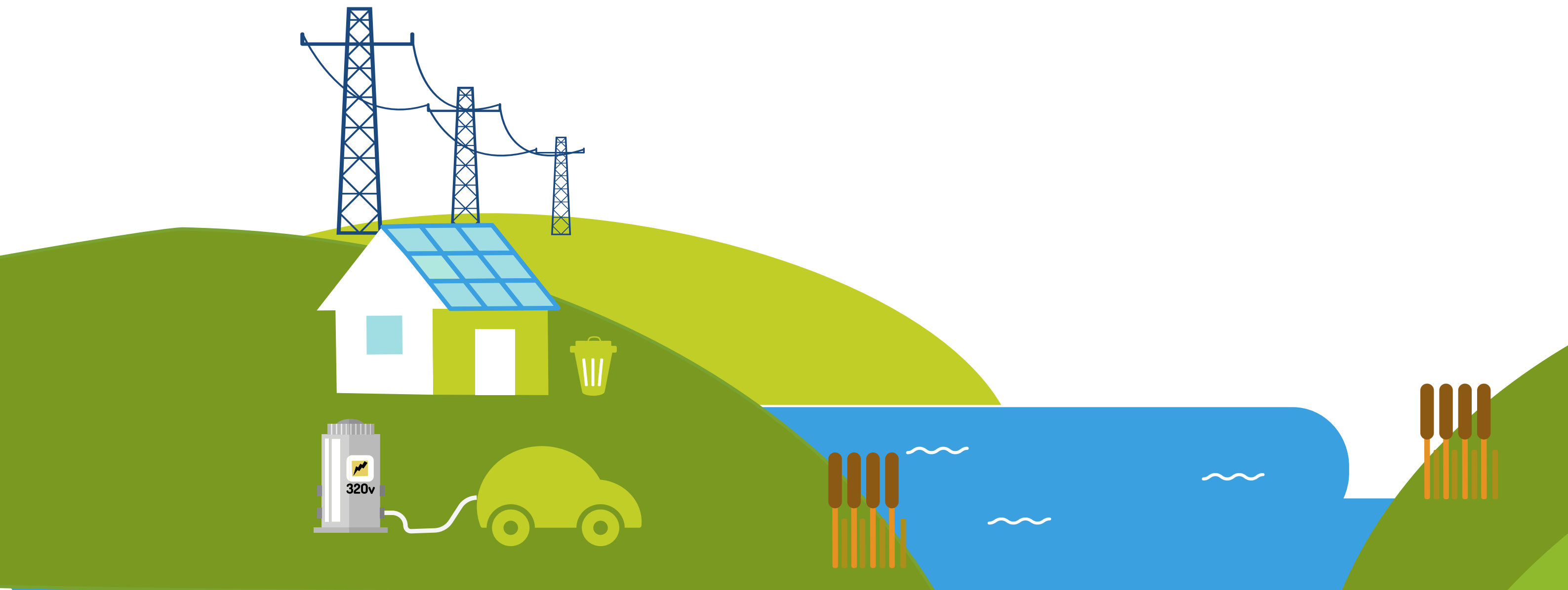
Table 4
Proposed and actual spend: January 2015 to June 2017 (£000s)

Cost Category	Actual	Budget	Variance
Labour	709.4	1607.5	(898.1)
Equipment	485.8	574.0	(88.2)
Contractors	1639.0	1861.3	(222.3)
IT	86.0	86.0	0.0
IPR costs	0.0	0.0	0.0
Travel and expenses	87.5	110.5	(23.0)
Payments to users	209.8	650.0	(440.2)
Contingency	348.9	553.7	(204.8)
Decommissioning	0.0	0.0	0.0
Other	40.0	40.0	0.0
Totals	**3606.4**	**5483.0**	**(1876.6)**

Our labour needs are monitored regularly to make sure the right resources are allocated to the project. These costs remain under budget over the full lifecycle of the project. As such, recruitment processes are under way for additional resource for the remainder of the project to ensure the satisfactory completion of all project deliverables.

Payment dates for contractor spend have been realigned with the revised system studies and field trial schedules, including the revised timescales agreed for Work Package 2.5: Wind.

Actual spend on payments to users is consistent with the schedule of the project field trials, including the adjustments made to the timeline for Work Package 2.1: Demand Side Response.



Successful delivery reward criteria (SDRC)

GE Grid Solutions

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

Work Package 1: Monitoring and Control System – Application Development – Revision Completed

GE Grid Solutions delivered a report outlining revisions to the applications designed and developed for fast frequency response. The report was issued on 24 March 2017.

The project has now moved into the demonstration phase, during which GE Grid Solutions' control platform and power systems applications will be validated through technical field trials at various project partner deployment sites. Multiple site acceptance tests have already been successfully completed at project partner sites. The academic partners have designed their joint academic test plan as well as their respective test cases. They will continue to run tests to validate the monitoring and control schemes.

All project partners

Knowledge dissemination event

All project partners hosted a hugely successful second knowledge dissemination and stakeholder engagement event at the University of Strathclyde's Technology Innovation Centre on 14 March 2017.

Successful delivery reward criteria for the next reporting period

There are seven SDRCs due in the next reporting period of July to December 2017, as shown below in Table 5.

Table 5
SDRCs for the next reporting period: July to December 2017

Description	Due Date	Status	Comments
Monitoring and control system developed successfully: Control platform development: Revision completed	31 July 2017	Green	-
Response analysis from service providers: CCGT power stations	31 July 2017	Red[*3]	See below
Response analysis from service providers: Windfarm	31 July 2017	Red[*3]	See below
Response analysis from service providers: PV power plant	31 October 2017	Green	-
Response analysis from service providers: Demand-side response	30 November 2017	Green	-
Successful validation of response: Successful delivery of representative models and validation of trial results using the models	30 November 2017	Green	-
Successful development of new enhanced frequency response service as part of new balancing services	31 December 2017	Amber[*3]	See below

[*3] These activities are considered amber or red because they are unlikely to be completed by the original due date. However, they will all be completed in advance of project closure in March 2018. In line with proposed Network Innovation Competition (NIC) governance changes announced by Ofgem, the project steering committee is of the opinion that these "non-material" changes are deemed acceptable. This is to be formally confirmed with Ofgem in due course.

Future successful delivery reward criteria

The one remaining SDRC after this reporting period is: recommendations regarding the implementation of the new service. This is due by 31 January 2018.

This is alongside the annual requirement to host a project knowledge dissemination and stakeholder engagement event.

Learning outcomes

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

Work Package 1: Monitoring and Control System

This reporting period has focused on demonstrating the monitoring and control system, as well as handing it over to project partners for validation and field trials.

GE Grid Solutions worked with academic and commercial project partners to agree on deployment scope, set-up and configuration. Deployment reports and site acceptance test (SAT) procedures were issued to relevant partners for review and execution. GE Grid Solutions provided onsite support for the installation and integration of the PhasorController units at various deployment sites. Completed SATs are as follows:

- 8 February 2017 – University of Manchester (RTDS)
- 22 February 2017 – University of Strathclyde (PNDC)
- 8 March 2017 – Belectric (solar PV power plant).

Further SATs for the remaining project partners will continue throughout the next reporting period.

After the above three SATs were completed, GE Grid Solutions provided further support by answering questions and addressing issues raised subsequently by project partners. The validation of fast frequency response schemes will continue during the next reporting period and the remainder of 2017.

In addition, a report outlining revisions to the monitoring and control system applications designed for fast frequency response was issued by GE Grid Solutions on 24 March 2017.

Work Package 2.1: Demand-Side Response

Through continuing engagement with industrial and commercial electricity customers, Flexitricity now has all the necessary contracts in place for the trial phase of the project. Preparation and installation work is now under way at around half of the sites. This period has confirmed our expectation that EFCC needs a high level of technical diligence when dealing with sites and testing equipment for deployment. Participating sites include:

- a major chemicals producer with a load of approximately 6MW in the static RoCoF trial
- a district heating scheme with two 3MW combined heat and power (CHP) engines in the real inertia trial
- a horticultural company with two 1.5MW CHP engines in the real inertia trial
- a wastewater treatment site with two participating loads – sludge pumping and aeration in the dynamic RoCoF trial
- a wastewater pumping station in the dynamic RoCoF trial
- a cold store in the dynamic RoCoF trial.

This exercise has demonstrated the potential for a broad range of industrial and commercial customers to use a commercial EFCC service.

Through the EFCC project, Flexitricity has developed in-house capability to inject simulated frequency events into site equipment

and to measure accurately how the loads respond to these stimuli. Inertia response has more onerous requirements than conventional frequency response, so validating the capabilities of different loads could impose a significant per-site cost – type testing could reduce this burden. This is considered a commercial matter for the post-project period.

During the trial phase we will take detailed online measurements of performance. This is particularly important at the two CHP sites that are delivering the 'spinning inertia' form of the service because we need more in-depth information, to identify how CHP engine controls interact with system frequency at short timescales.

Work Package 2.2: Large-Scale Thermal Generation

Centrica's activities to date have centred on testing revised frequency control logic before implementation on a gas turbine at South Humber Bank power station. Now that it has been implemented, the revised frequency control logic has been tested by observing how frequency injection tests change the active power output. The test results have been encouraging and broadly in line with simulation results. The revised frequency control logic remains in place, although it is not active. This allows power station staff to analyse how the revised frequency control logic would have responded to actual power system events.

As demonstrated at the first EFCC knowledge dissemination and stakeholder engagement event, Centrica's revised frequency control logic has the potential to speed up the delivery of frequency response. Using computer simulation, Centrica showed that initiating frequency response by using rate of change of frequency (RoCoF) could increase the speed of delivery of frequency response by up to three seconds.

Moving on from computer-based simulation, Centrica carried out more simulations using a stand-alone version of the CCGT distributed control system (DCS), housed in racks. This set-up allowed Centrica to make further modifications to the revised frequency control logic. One aspect of the simulations that was particularly important – and crucial to Centrica's success – was to explore how this revised frequency control logic meshes with existing frequency control logic. The team had to be certain that the RoCoF-based initiated frequency response would not cause any unintended consequences to the plant at South Humber Bank or to the stability of the wider power system.

Once Centrica was satisfied that the revised frequency control logic was robust enough to be used on the actual plant, it was downloaded onto the live DCS during an outage of the CCGT module. Centrica also drew up a programme for frequency injection tests, which was then agreed with National Grid.

The testing was carried out during two days in early March 2017. It involved a series of frequency injections to see how the actual plant behaved in response to a simulated system frequency. The tests were successful and were presented at the second EFCC knowledge dissemination and stakeholder engagement event in Glasgow. Figure 1 illustrates the improvement in frequency response delivery during the early stages of a simulated frequency event.

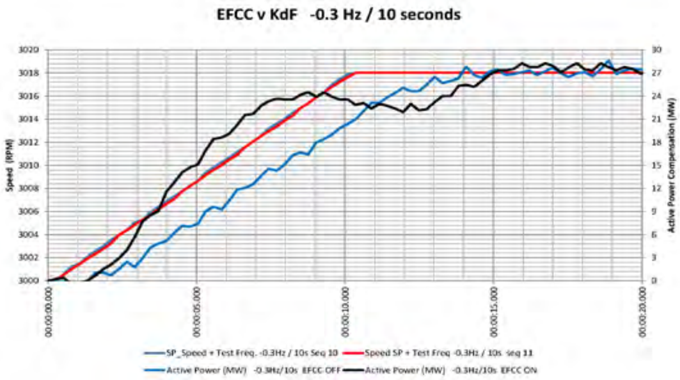


Figure 1: Overview of results of frequency injection testing

Although the test results were generally considered successful, the interaction between conventional frequency response (KdF) and RoCoF-based frequency response is very important to all concerned. Although the revised frequency control logic is not being used in a live environment, Centrica is able to analyse how it would respond to actual power system events using the CCGT module's DEPP system – a fast data recorder with a resolution down to 40ms.

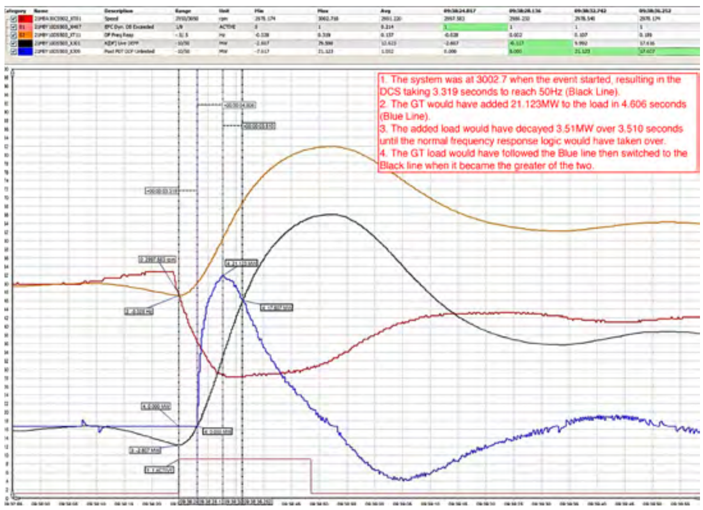


Figure 2: Comparison of response from both sets of frequency control logic to an actual system event

On Tuesday 9 May 2017 there was a low frequency event caused by the instantaneous loss of import of 1000MW from the French interconnector. This provided an opportunity to examine how the revised frequency control logic would have responded to an actual power system event. From a RoCoF perspective this was an interesting scenario. South Humber Bank power station is situated approximately 250 miles away from the source of the event and – as is being learned and demonstrated elsewhere in this project – this was used to identify that measured RoCoF is by no means uniform across the entire power system.

Initial analysis of this actual power system event, shown in Figure 2, is encouraging. It gave rise to some new areas of focus, particularly in the context of the interaction between the conventional KdF-based frequency response and the RoCoF-based frequency response. What was particularly interesting about the 9 May event was that the system frequency was above 50.0Hz at the point when the event occurred. So if South Humber Bank power station had been used for response by National Grid at that time, it would have been providing a high-frequency response at the start of the frequency drop. Centrica is currently examining how the withdrawal of the conventional KdF-based high-frequency response and the delivery of the RoCoF-based frequency response would have interacted.

As we move into the summer and experience times of lower inertia than is generally the case in winter, more real system events should provide further data for Centrica to fine-tune the revised frequency control logic.

Work is also ongoing with GE Grid Solutions to determine the optimal method for installing the local PhasorController at South Humber Bank, to integrate South Humber Bank's CCGT fully with the wider EFCC project. This work has determined that Centrica will need to install fibre optic cable between the 400kV substation and one of the power station module electronics rooms.

Work Package 2.3: Solar PV

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

- installed all the required components at the solar PV power plant
- continued to develop the software for the Belectric hybrid controller, including a framework and new control algorithms
- integrated a cloud movement camera and a solar PV model into the Belectric hybrid controller – these are used to calculate the resource attributes at any moment in time
- integrated the GE Grid Solutions PhasorController into the solar PV power plant – communications between the Belectric hybrid controller and the GE Grid Solutions PhasorController were developed and commissioned in close collaboration with GE Grid Solutions using the communication protocol IEC 61850 GOOSE
- integrated the GE Grid Solutions PMU measurement equipment into the collecting station of the solar PV power plant and commissioned the PhasorPoint measurement software in collaboration with GE Grid Solutions
- developed a solution for the distributed data stream management of PMU protocol data and the division between internal and external data – the distributed data stream management of PMU log data is still under development
- carried out a successful site acceptance test and the PMU equipment is now operational
- created and shared a test plan to demonstrate the frequency response capabilities of the solar PV power plant.

The following learning outcomes have been 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 done by shifting down the operating point of the solar PV plant, but it's a cost-intensive solution and can only be applied 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 has been demonstrated and is working with the Belectric controller components within the solar PV power plant.

Also, as explained earlier in this report, the concept of a Belectric hybrid solar PV and battery storage resource is still being pursued. Belectric continues to work towards this and achieved the following objectives and learning outcomes 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 can be achieved using solar PV only
- the site is being prepared for the installation of the battery storage unit – once installed the battery storage unit will be commissioned.

Work Package 2.5: Wind

During this reporting period, we have continued to work with DONG Energy and Siemens to develop an agreed approach to potential wind turbine tests. These tests will aim to demonstrate a windfarm's ability to provide fast, initiated frequency response.

The use of a GE Grid Solutions PhasorController during these windfarm tests is no longer within the project scope. The park pilot in the windfarm can measure the power system frequency and instruct the windfarm to provide the required frequency response in the specified form. So there's no need to use a third-party asset.

A stage-one contract was signed in October 2016 for trials to take place on test turbines. This work is already under way and has so far achieved the following:

- analysed field trials on a test turbine – although the first field trials didn't provide a full mapping of the inertial response performance across the entire operating range, they validated that the loads are inside acceptable levels to proceed with more detailed field trials for this turbine model. This testing of inertial response on the test turbine was run on 14 June 2017. Additional tests at other wind conditions are to follow shortly
- performed a set of simulations to get an estimate of the expected performance in the entire wind range – the simulations used the BHawC aero-elastic code, a validated structural model of the SWT-7.0-154 turbine and the turbine controller
- carried out initial tests – these indicate that 10% of available power will not be available at all production levels. All further simulations are to be based on 5% magnitude for a duration of 10 seconds
- presented field trial results and a subset of the simulations at the EFCC knowledge dissemination and stakeholder engagement event on 14 March in Glasgow.

Further field validation will need to be carried out to confirm these results. Software has been modified and prepared for field trials during the spring at various wind conditions. These trials will validate the latest learnings and will document the response and the recovery profile for multiple wind conditions.

As part of the stage-one works, DONG Energy will also 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.

A stage-two contract for trials on a fully operational, commercial windfarm is still being discussed. One of the main outstanding challenges in finalising the stage-two contract is to determine how liabilities will be shared during these activities.

Work Packages 3 and 4: Optimisation and Validation

(i) The University of Manchester

The University of Manchester has been working on system studies and service provider modelling in DIgSILENT PowerFactory software and real-time digital simulator (RTDS) hardware in the loop (HiL) testing to validate the performance of the GE Grid Solutions' monitoring and control system (MCS).

Validation activities through system studies using DIgSILENT PowerFactory

The main challenge of EFCC system studies was that the detailed models of the various response provider technology types were not made available to the University of Manchester. Without detailed models, any fast frequency control scheme will be based on generic, and therefore possibly inaccurate, assumptions about technology capabilities. As a result, true performance will not align with simulated performance.

To overcome this issue the University of Manchester has developed detailed models of doubly fed induction generator (DFIG) based wind energy conversion systems and combined cycle gas turbines (CCGTs) in DIgSILENT PowerFactory for use in system studies. These models are integrated into the simple but practical two-area Kundur network model, as well as a large-scale, complex, 36-zone GB network model, and their frequency response is assessed.

This can be summarised as follows.

- **Integration of CCGTs into the representative two-area and 36-zone GB test power networks and the assessment of frequency response**
  During this stage the University of Manchester investigated the main components of CCGTs. It also addressed the control loops of the CCGTs that either directly affect the response of the power plant to power system disturbances or have an effect on the design or operation of the plant.

  The model incorporated gas turbine, heat recovery steam generator and steam turbine, as well as speed control, temperature control and inlet guide vane control. This is illustrated in Figure 3. The appropriate model of CCGTs for short-term dynamic study following a frequency excursion was simulated in DIgSILENT PowerFactory. The designed and developed CCGT model and its controllers were tested on a two-area test system as well as a large-scale, complex, 36-zone GB network model.

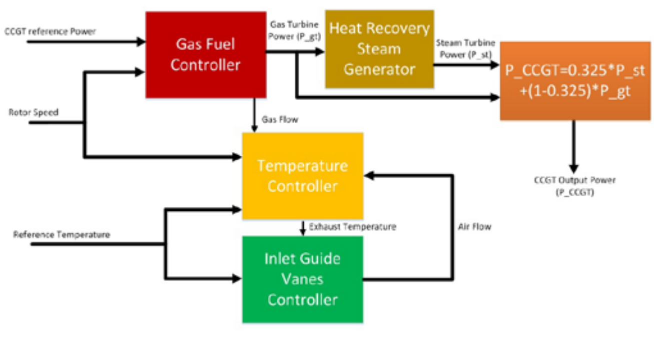


Figure 3: CCGT block diagram model

The University of Manchester investigated the dynamic impact of CCGTs on small-signal stability and electromechanical modes using modal analysis, and evaluated the impact of high penetrations of CCGTs on frequency response. It also used time-domain dynamic studies to validate high CCGT integration effects in full and partial load operation modes. It also evaluated the condition of different areas from the frequency nadir and the maximum rate of change of frequency (RoCoF) for an n-1 contingency and a worst-case scenario.

Simulation results from the dynamic performance of the CCGT in two operational modes of full and partial load showed that although RoCoF of the whole system is identical in these two scenarios, the frequency nadir and steady state frequency of the CCGT in full load are less than they are in partial load. The results showed that with extra CCGTs on the power system, large frequency decay in nadir and steady-state conditions would be more probable if the CCGTs are on full-load operation. The system operator would therefore need to review its frequency control approaches to operate CCGTs in partial mode, in order to enhance RoCoF, frequency nadir and steady-state frequency deviation.

- **Integration of DFIG into the representative two-area and 36-zone GB test power networks and the assessment of frequency response**
  Based on a GE manufacturer report, the University of Manchester developed a model, as illustrated in Figure 4, to study DFIG's short-term dynamic response to a system frequency deviation.

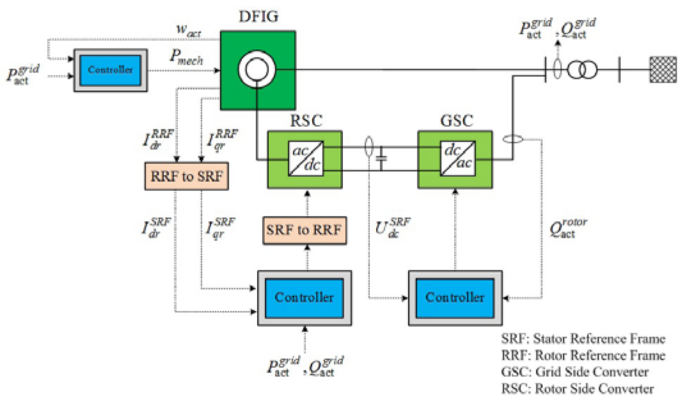


Figure 4: DFIG block diagram model

During this stage the team focused on describing and modelling the main DFIG components within DIgSILENT PowerFactory: rotor side converter, grid side converter, pitch angle controller, speed controller and active power controller. It also carried out an analytical investigation of the available inertia and droop responses, based on de-loading from the DFIG, to help support the inertial and primary frequency control in power system networks.

The model was used in conjunction with the simple but practical two-area test system and a large-scale, complex, 36-zone GB network model to study the impact of increasing levels of DFIG generation on frequency control. The team carried out modal analysis and dynamic time-domain simulations to study the power system frequency response and investigate how DFIGs can affect this response on a test power system with wind penetration levels of low (25%) and medium (50%).

Learning outcomes cont.

The simulation results showed that the frequency nadir and steady-state frequency deviation deteriorated when DFIGs were integrated into the network without governor-like primary controllers.

The team observed that the two quantities are improved by increasing the DFIG penetration levels from 25% to 50% – meaning that higher wind penetration allows more responsive frequency regulation of the system, provided that the DFIGs are equipped with the proposed governing function.

RTDS HiL testing

The University of Manchester's goal within the EFCC project is to provide the necessary expertise and equipment to carry out a range of Hardware in the Loop (HIL) testing on the monitoring and control system (MCS) manufactured by GE Grid Solutions. The performance of GE Grid Solutions' MCS needs to be validated through a variety of system cases and operational conditions. Those scenarios and system cases which couldn't be included in actual field trials were examined by real-time digital simulation facilities in Manchester.

In this project, the University of Manchester copes with the real-time simulation phase of testing using its RTDS facilities to accomplish HiL testing of the EFCC scheme.

The HiL tests will focus on the following items:

- **Power system and component modelling in RSCAD software (the simulation environment used by RTDS)**
  The University of Manchester developed the power system test networks in RTDS. It also studied and configured the communication links between RTDS and the MCS.
  It developed two power system test models for testing and validation of the MCS:
  - a two-area test system
  - a GB network test system, which can be considered as an appropriate representation of the actual GB system.

  Although the bulk of the studies used the above two test systems, the 36-zone test system was used to demonstrate proof of concept of EFCC for a larger system.

  The test systems were selected based on the needs of the test and the fact that the hardware available places limitations on the size of the test system and the complexity of the equipment models that can be included.

- **Real-time HiL simulation of EFCC using RTDS capabilities to validate the performance of the MCS developed by GE Grid Solutions**
  In February 2017, site acceptance testing was carried out at the University of Manchester, using procedures designed to verify and exercise the controllers designed for the EFCC project. These included the Phasor Data Concentrator (PDC), as well as controller devices like the PhasorControllers and PhasorPoint.

  The following GE Grid Solutions hardware was installed: a central supervisor (CS), two regional aggregators (RAs) and four local controllers (LCs). GE Grid Solutions also provided the University of Manchester with the following software:
  - Straton PLC IDE
  - licence for Straton
  - library files for Straton
  - PhasorPoint installation package.

Before the SAT demonstration, virtual PMU components of the RTDS using the IEEE C37.118.2 protocol – an extremely realistic environment – were configured for the two-area test system and the GB network test system models. These components monitor power system quantities such as voltage, current and frequency. The GTNET-GSE hardware component was also configured for bidirectional communication between RTDS and the EFCC local controllers via IEC 61850 GOOSE, for the two-area test system and the GB network test system models.

When an event is detected, the EFCC scheme, via the local controllers, sends control commands to the resources modelled in RTDS using IEC 61850 GOOSE. The HiL configuration allows testing of the EFCC scheme's capability to detect events in a timely way: to verify that the EFCC scheme instructs the correct amount of resource at the correct time. This allows the team to assess how effective controls are in helping to manage frequency in a highly flexible and realistic environment.

To meet the testing requirements of the EFCC project, the University of Manchester developed some additional features for the test system models in RUNTIME simulation of RSCAD, including:
- dynamic inertia control panel
- disturbance control panel
- generation control panel
- short-circuit control panel.

The University of Manchester also focused on the RTDS-HiL testbed and communication set-up, as illustrated in Figure 5.

Figure 5: RTDS-HiL testbed and communication setup

Lessons learned from 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.

While doing the tests, the University of Manchester unearthed a bug within the demand-side response local controller (DSR-LC) and reported it to GE Grid Solutions for their evaluation and debugging of the DSR-LC wide-area response. GE Grid Solutions has identified a defect within the resource allocation block algorithm of the DSR-LC. There was a flip-flop in the logic, which was not being driven from the correct signal, so was not able to reset correctly when required. This issue has now been fixed and the algorithm revised and improved for the resource allocation block. GE Grid Solutions has made some further minor improvements, including:
- revised reset logic
- revised discrete trigger hold and recovery logic

- revised continuous response deployment during ramp-down followed by another event.

(ii) The University of Strathclyde

In the past six months, the team at the University of Strathclyde has been finalising the development of the testbed arrangements at the Power Networks Demonstration Centre (PNDC), commissioning the EFCC controllers and preparing all of the resources required for the formal tests.

This has included the following major activities.

- **Completed implementation of a dedicated Power-Hardware in the Loop (P-HiL) testbed**
  As outlined in the previous six-monthly report, the team has successfully developed and validated an effective control algorithm for the motor-generator at the PNDC. This algorithm allows the motor-generator to lock its output frequency and voltage phase angle with an external transmission grid simulated using the real time digital simulator (RTDS). This allows the PNDC network to be synchronised with a simulated wider grid.

  During the intervening six months, the team has closed the loop in order to feed signals relating to actual PNDC network behaviour back to the simulated grid in RTDS. This means that any changes in behaviour within the actual PNDC network (such as voltage levels and real and reactive power exchanges with the external simulated grid) are now passed between the RTDS simulated main grid system and the actual local PNDC system via the motor-generator set and current feedback loop.

  Consequently the loads and the EFCC controlled resources at the PNDC can be scaled in the simulated overall grid system to a desired size that is realistic in terms of future EFCC implementations. Any frequency response instructed by EFCC using the PNDC resource will be reflected accurately within the wider system simulation, so the complete P-HiL testbed has been successfully established, tested and reported in publications.

- **Site acceptance test (SAT) at PNDC**
  The SAT relating to the GE Grid Solutions' supplied EFCC hardware was completed during March 2017. The controllers were commissioned and all predefined tests were carried out satisfactorily.

- **Validation of the communication interfaces between the EFCC controllers and the PNDC facilities**
  The University of Strathclyde comprehensively tested the communication between the EFCC controllers and the PNDC facilities. The tests involved using the PNDC's own communications switch interfaced with the various communicating devices involved in the EFCC scheme. The team specified and procured a suitable communication emulator for testing the impact of communication system latency and jitter on EFCC system performance. This will be used in the formal testing programme later in the project.

- **Familiarisation with the EFCC scheme and configuration of the EFCC controllers**
  The team at the University of Strathclyde and the PNDC has also been familiarising itself with the hardware and software associated with the EFCC scheme. For example, using PhasorPoint for monitoring and recording controllers' and PMUs' outputs and understanding the settings and effects of the various parameters that can be configured within the controllers. Assisted by GE Grid Solutions, the team has also established controller settings that are suitable for the tests to be carried out at the PNDC.

- **Initiation of the first stage of the formal test programme**
  The team has started the first stage of formal tests to validate the EFCC scheme in local operational mode. More detail will be contained in the next project progress report.

- **Knowledge dissemination**
  The team has worked closely with National Grid and other partners to share the knowledge generated from the project through papers, dissemination events and sharing of open-source software. The knowledge dissemination section of this report provides more information about this.

Work Package 6: Commercial

The full development of the EFCC commercial service started in January 2017. The work package focuses on how the commercial service could be developed and offered to the industry. It aligns with other industry initiatives, particularly the product simplification strategy outlined in the System Needs and Product Strategy* document.

The work package will require collaboration with the University of Manchester, which will be helping National Grid develop the commercial service, and with GE Grid Solutions because of the potential impact on the optimisation algorithm. Technical information from the project's response providers and results from their field trials will also be used to help with the development of the commercial framework.

Work Package 7: Communications

The project continues to consider what is needed for the data communications infrastructure to support the GE Grid Solutions' monitoring and control system. Demonstrations at the University of Manchester and the University of Strathclyde's PNDC, which form part of Work Package 4: Validation, will investigate communications latency and the capabilities of fast, round-trip control of the scheme. The results of these investigations will be available at the end of the project. National Grid will also assess what data communications will be required from an operational perspective to support the monitoring and control system.

National Grid will also carry out a demonstration of GE Grid Solutions' monitoring and control system using the central supervisor, regional aggregator and local controller units. The scope of the demonstration is being finalised and system simulation and/or network trials are being considered.

A technical assessment of how the monitoring and control system would integrate with the Electricity National Control Centre (ENCC) is being considered – information about this will be included in the project's closure report.

* http://www2.nationalgrid.com/UK/Services/Balancing-services/Future-of-balancing-services/

Intellectual property rights

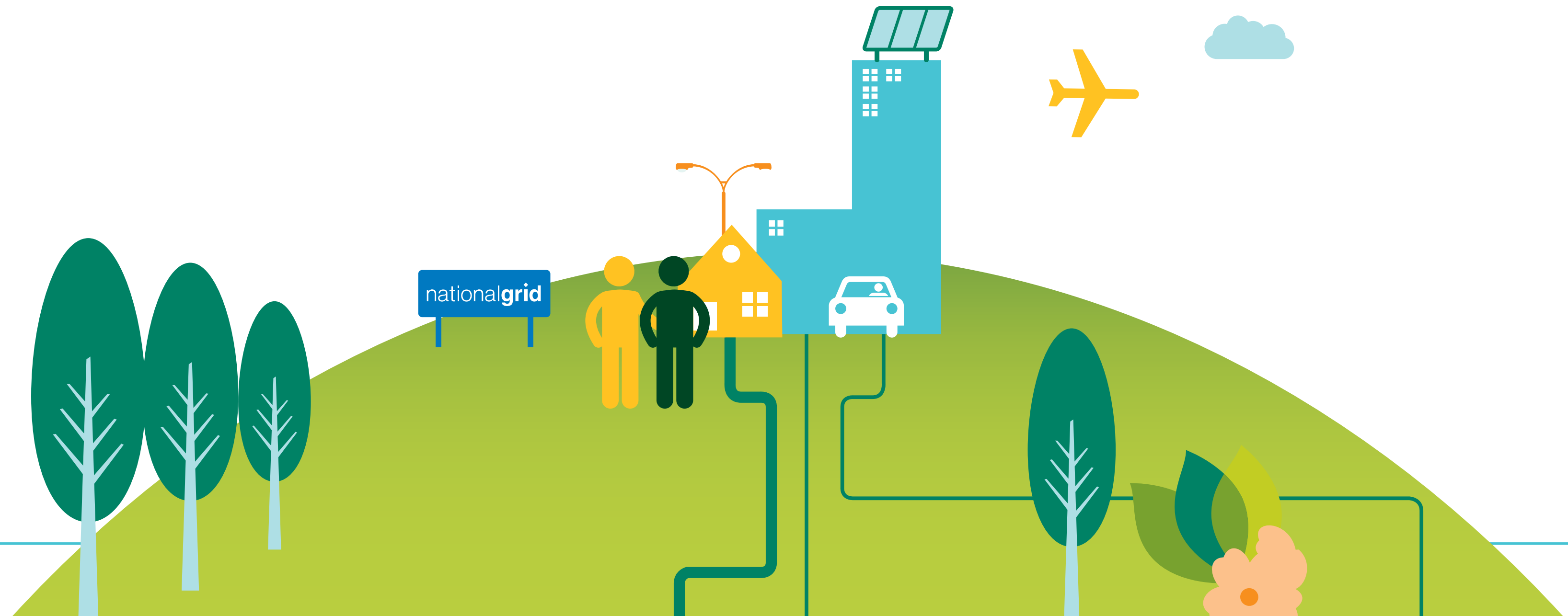
GE Grid Solutions and all other project partners will make versions of their reports and documents available on the project website wherever possible, in order to meet the requirements to publish intellectual property developed within this project. Full versions will be made available to all project 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.

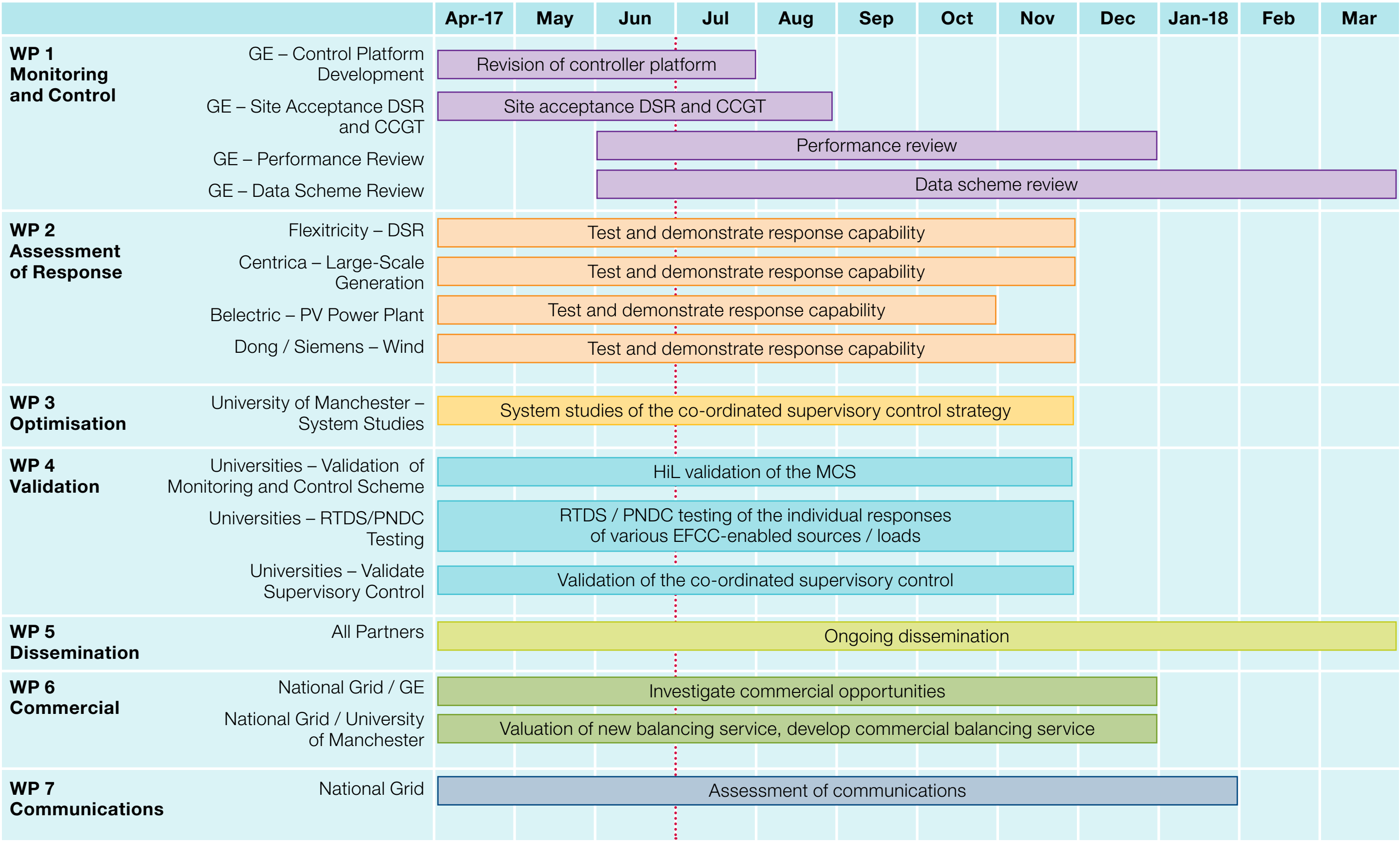
Risk no.	Work streams / area	Risk description	Cause	Consequence	Risk owner	Likelihood (1-5)	Financial impact (1 - 5)	Reputational impact (1 - 5)	RAG	Escalation route	Action plan	Control opinion
5	General	Significant changes to the GB electricity system during the project.	Priorities or strategies for 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	4	20	Steering Group	We will consider future developments and scenarios. We will ensure usefulness of solution matches planning of system. Providing regular project updates to all project partners.	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	5	2	4	20	Steering Group	Knowledge of, and responsibility for, project to not rely with one person. Ensure there is documentation and guidance to help anyone joining project team. Thorough handover processes to be in place.	Partially 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.	Effective
56	WP2.5 - Wind	EFCC project needs to agree with DONG and Siemens and associated Joint Venture partners for the use of wind farm.	Delay in agreeing use of wind farm.	Delays to work package and overall project outcomes.	National Grid	4	5	5	20	Project Manager	Agree schedule of tests and activities early in the negotiation process and start contractual discussions in parallel. Contractual discussions taking place and approaching completion.	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 reviews of planned deliverables, identifying any issues with delivery, investigating alternatives and escalating to Steering Group.	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 test plan starting and quality of test outputs.	Project Manager	5	3	4	20	Steering Group	Escalation to Steering Group for discussion and resolution.	Partially Effective



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, Electricity Policy and Performance Manager, on behalf of Richard Smith, the project sponsor. Every effort has been made to make sure that all information in the report is true and accurate.

Appendix A: EFCC project plan



Appendices cont.

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.	Decision is taken by partner to leave the project. Reason could be commercial, operational, etc.	Work is lost or unable to start and the usefulness of the project results is reduced or project is delayed.	Project Manager	3	2	4	12	Steering Group	Ensure 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	4	20	Steering Group	We will consider future developments and scenarios. We will ensure usefulness of solution matches planning of system. Providing regular project updates to all project partners.	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	5	2	4	20	Steering Group	Knowledge of, and responsibility for, project to not rely with one person. Ensure 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	4	3	3	12	Project Manager	All partners have been assessed based on reputation, track record and responses to NG tender. Ensure that price is not the prioritised criteria. Ensure quality control procedures are in place and followed 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	3	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	4	3	3	12	Project Manager	Thorough checks before tests. Clear understanding of equipment capabilities. Particular stress points identified. Spare parts and repairs lined up.	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	4	3	3	12	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	General	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, spares, etc. are higher than expected.	Excessive OPEX costs compared to current alternatives.	National Grid	4	3	3	12	Project Manager	Financial impact of 3 defined in original business case. Maintenance requirements and spares etc. identified during tender evaluation. Further work to be carried out to fully determine OPEX requirements.	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	4	2	3	12	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	4	5	4	20	Project Manager	Work closely with National Grid and partners to ensure that new comms links not critical to project success. Ensure 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	1	3	15	Project Manager	Outages identified and incorporated in scheme requirement document.	Partially Effective
20	General	Commissioning procedures encounter problems.	Commissioning procedures are unclear or untested, being difficult to complete in practice.	Delays in commissioning the project.	National Grid	4	3	3	12	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 managing the finance budget to ensure that it stays within original project budget.	Partially Effective
22	Health, Safety & 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

Appendices cont.

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
23	WP1 - Control System	Technology partner fails to deliver suitable product on time.	Problems with design and build.	Project is delayed.	GE	1	2	2	2	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 established/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).	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 in place 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 test purposes. 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).	Partially 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.	Effective

Appendices cont.

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
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. There must exist a sufficient information exchange between the controller and the individual resources so that resources can be called upon in a timely manner.	Lack of comms path or interoperability issues between the controller and the resources may lead to delayed initiation of response and reduced ability of the central control scheme 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
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.	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.	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.	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 a sufficient period to determine the control scheme performance.	The selected control scheme will be unable to effectively deploy resources to arrest a frequency excursion.	National Grid	3	3	3	9	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
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 proving proof prior 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.	Partially 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 asessed 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.	Partially 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.	Effective
36	WP2.1 - DSR	DSR trials prove infeasible.	Complex technical interaction with existing commercial site processes.	Ability of DSR to deliver EFCC not proven.	Flexitricity	3	4	4	12	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) prior to trials.	Partially Effective
37	WP2.1 - DSR	Total delay between detection and action too long for distributed resources including DSR.	Long signalling chain including communicating with remote sites.	Cannot dispatch certain 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

Appendices cont.

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
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 ready too late for trial.	Flexitricity	3	3	3	9	Project Manager	Start EP recruitment during phase 1; show flexibility on trial dates and durations.	Partially Effective
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	3	2	3	9	Project Manager	Detailed models of Doubly Fed Induction Generator (DFIG) and Combined Cycle Gas Turbine (CCGT) are developed in PowerFactory for system studies and other service providers modelling are on-going.	Partially 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 roll-out may be severely impacted by issues not flagged during the validation phase.	Universities	2	3	3	6	Project Manager	Reduced substation model of 36-zone GB system has been simulated and modelled in RTDS. The required data are extracted from PowerFactory model and then RTDS model has been built.	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	Ensure knowledge sharing is a priority of project. 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	Ensure that 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	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.	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.	Partially 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.	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	3	2	2	6	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.	Effective
56	WP2.5 - Wind	EFCC project needs to agree with DONG and Siemens and associated Joint Venture partners for the use of wind farm.	Delay in agreeing use of wind farm.	Delays to work package and overall project outcomes.	National Grid	4	5	5	20	Project Manager	Agree schedule of tests and activities early in the negotiation process and start contractual discussions in parallel. Contractual discussions taking place and approaching completion.	Partially 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	2	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	2	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
61	WP2.5 - Wind	Revised timeline for wind workpack does not coordinate 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	4	3	4	16	Steering Group	Work with partners to identify and resolve contractual issues and escalate any modelling issues.	Partially Effective
62	WP3 - Optimisation	Revised timeline for University of Manchester affects work deliverables of the project.	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	4	3	4	16	Steering Group	Revised project timeline agreed with University of Manchester, with associated project dependencies identified and managed.	Partially Effective

Appendices cont.

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
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 monthly have review of planned deliverables, identifying any issues with delivery, investigating alternatives and escalating to Steering Group.	Partially Effective
64	General	Handoffs between partners are delayed.	Handoffs are not clear in the plan or not proactively managed to ensure the planned timeline is kept.	Delays compromising other work deliverables.	Project Manager	5	3	3	15	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.	Additional trial equipment requirements identified, which are not immediately available.	Delay in testing phase, knocking on to delaying the general project timeline.	University of Manchester	3	3	3	9	Steering Group	Additional trial equipment (such as GPS grandmaster clock and managed ethernet switch) are delivered with three months' delay.	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 test plan starting and quality of test outputs.	Project Manager	5	3	4	20	Steering Group	Escalation to Steering Group for discussion and resolution. UoM are developing test template.	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
68	WP7 - Comms	Delay in delivering the 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	4	20	Steering Group	Recruit specialist resource and draw upon existing expertise within NGET.	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	4	20	Steering Group	Recruit specialist resource and draw upon existing expertise within NGET.	Partially Effective

Closed risks

8	General	Technology cannot be easily upgraded.	Monitoring and control technology and/or response equipment is designed without full consideration for future developments.	Technology is less useful in the future as the electricity system continues to develop. Required upgrades are costly or impossible.	GE	4	2	3	12	Project Manager	Future requirements considered and built into specification. Flexibility has been built in. Scheme updates can be facilitated through library updates.	Effective
10	General	Academic service providers can't recruit appropriate staff to work on the project.	Lack of suitable candidates or interest in the project.	Trials are limited or can't take place. The suitability and performance of the technology is not established.	Academic Project Manager	1	1	1	1	Project Manager	Academics have a large internal candidate-base of experienced post-doctoral research assistants. Reputation and facilities of partners will attract high-calibre candidates. Process for advertising for suitable candidates is progressing. A PhD student has been assigned for UoM. The RA started in January. Student already recruited for UoS. Closed 16 May as recruitment has taken place and staff are in situ.	Effective
35	WP2.1 - DSR	DSR recruitment: industrial and commercial electricity customers unwilling to participate.	I&C energy managers' workloads, comprehension of the proposition, duration of trials, uncertainty of long-term commercial service, opportunity cost.	Not proved that DSR can deliver EFCC.	Flexitricity	4	2	4	16	Project Manager	Use Flexitricity's extensive existing customer base and contracting process for recruitment. Risk closed. Merged with risk 34.	Effective
42	WP2.4 - Storage	Local problems delay installation and commissioning.	Issues around grid connection and accessibility cause delays.	The project is delayed.	Belectric	3	2	3	9	Project Manager	Careful and detailed up-front planning; project plan not too tight. Closed as workpack 2.4 is descoped.	Effective
51	WP2.4 - Storage	Ofgem needing to accept storage in Smarter Frequency Control.	Insufficient argumentation in front of Ofgem.	Storage combined with PV not part of Smart Frequency Control.	NG/Belectric	2	3	3	6	Project Manager	Prepare justification for battery storage to Ofgem. Closed as workpack 2.4 is descoped.	Effective
52	WP2.5 - Wind	EFCC project needs to agree with all Joint Venture partners for use of Lincs, Lynn or Inner Dowsing.	Delay in agreeing use of wind farm.	Delays to project	Project Manager	1	1	1	1	Steering Group	Communication taking place with Dong and Siemens. Risk closed. Merged with risk 56.	Effective
57	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 may be needed. Extra effort may be required to develop, configure and test extra controller units.	GE	3	2	2	6	Project Manager	GE will further develop controller concepts and schemes. GE will work with project partners to establish suitable demonstration set-ups. Impact assessment will be conducted to assess potential extra requirements in terms of hardware and/or effort. Project partners to confirm/justify number of controllers with National Grid. GE to plan procurement internally. Closed. Partners have confirmed number of controllers.	Effective

National Grid
National Grid House
Warwick Technology Park
Gallows Hill
Warwick
CV34 6DA

www.nationalgrid.com