Notes on Completion: Please refer to the appropriate NIA Governance Document to assist in the completion of this form. The full completed submission should not exceed 6 pages in total.

NIA Project Registration and PEA Document

Date of Submission

Jun 2019

Project Reference Number

NIA_NGSO0026

Project Registration

Project Title

Demonstration of Virtual Synchronous Machine control of a battery system

Project Reference Number

NIA_NGSO0026

Project Licensee(s)

National Grid Electricity System Operator

Project Start

June 2019

Project Duration

1 year and 1 month

Nominated Project Contact(s)

Ben Marshall

Project Budget

£275,000.00

Summary

The National Grid System Operator has produced a potential functional specification for grid supporting requirements within the Grid Code Virtual Synchronous Machine (VSM) expert working group. These may be provided by a range of potential approaches including traditional synchronous generation, supplementary measures such a flywheels and synchronous compensation. Another approach as discussed in the group is a VSM control philosophy applied to convertor-based technologies to meet this specification.

Whilst the functional needs have been defined in the VSM work group these may be delivered in a variety of ways and our testing, modelling and specification needs to ensure appropriate performance is delivered. This requires innovative new testing and modelling approaches to be examined against the new technology options which have been proposed to ensure what is developed is helpful to both the operator and user.

Nominated Contact Email Address(es)

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Problem Being Solved

The increasing penetration of non-synchronous generation has introduced challenges for transmission and distribution network operators. System inertia and system strength are decreasing nationally and at different rates regionally. The network is becoming more sensitive to frequency and voltage disturbances and inverter-connected assets are at risk of responding in undesirable ways, leading to more limited ability to recover the network following disturbances.

Meanwhile, traditional sources for supporting the network with inertia and fault current are contributing less to the operation of the system, and as such new sources need to be found to support normal operation and emergency planning.

National Grid Electricity System Operator (ESO) has discussed these challenges more fully across a range of System Operability Framework publications (available on our website). The ESO has also produced a potential functional specification for grid supporting requirements within the Grid Code Virtual Synchronous Machine (VSM) expert working group. These may be provided by a range of potential approaches including traditional synchronous generation, supplementary measures such a flywheels and synchronous compensation. Another approach as discussed in the group is a VSM control philosophy applied to convertor-based technologies to meet this specification. This work has been industry leading internationally, as will be any subsequent implementation as VSM has not

yet been implemented anywhere in the world for grid operation.

We are aware that many manufacturers are looking at delivering control solutions and that some have control behaviour that references the grid in such a way as to limit or inhibit the functional performance required. Other approaches appear to deliver what is required but now the full consequences of these approaches cannot be identified across the standard range of compliance tests.

Whilst the functional needs have been defined in the VSM work group these may be delivered in a variety of ways and our testing, modelling and specification needs to ensure appropriate performance is delivered. This requires innovative new testing and modelling approaches to be examined against the new technology options which have been proposed to ensure what is developed is helpful to both the operator and user.

Method(s)

This project will demonstrate a VSM control approach on an inverter-connected asset (a test battery) in a representative environment.

The project partners have identified a proposed approach to VSM that is understood to meet the requirements of the VSM specification for battery technology with minimal modification to existing convertor or battery hardware. For this project, they will provide a physical battery and convertor (0.6MW scale) with this control approach installed, together with RMS and EMT models reflecting the design. This provides the first opportunity to combine simulation analysis and testing of an actual physical design to ensure it realizes the intended specification.

The project will conduct a range of tests:

1. Voltage step tests
2. Fault ride through with actual physical faults deployed
3. Multiple fault ride-through event test
4. Frequency step tests
5. Frequency events
6. Phase angle step change tests.
7. Combined frequency and voltage depressions
8. Trial black-start energisation of PNDC network via the VSM-controlled Battery.

The precise conditions of the above tests will be flexed within the limits of time and resource available with the intention to ensure the performance of VSM is demonstrated without the effect of embedded protection or control elements acting to override that performance.

Across the tests there will be the capability within the PNDC to replicate the test in a parallel simulation study in an EMT modelling environment and an RMS modelling environment. The project will compare the delivered test performance to a simulated test behaviour as seen in a RMS study via DIgSILENT modelling and in a EMT simulation via PSCAD using DIgSILENT and PSCAD models provided by the project partners. This will provide assurance that they are displaying the same behaviour as the physical battery connected displays, and compare also to simulated synchronous generator behaviour.

From the range of tests the key “litmus tests of VSM” will be identified, which can then be developed more broadly to inform future process and data exchange.

The project is split into two parallel Work Plans

1. WP 1.1. Simulation study for demonstrating the inertia emulation capability using the battery and inverter models
2. WP 1.2. Testing the battery and inverters with the proposed controllers using physical network test environment

Reports will be completed on the findings of each work package and made available at project completion.

Scope

The project shall conduct a range of tests on an inverter connected to a battery with VSM convertor control on the Power Networks Demonstration Centre’s 11kV and LV isolated physical network.

Objective(s)

By testing physical performance in a controlled environment, it is possible to learn how best to demonstrate and facilitate VSM based solutions for batteries. This learning has the potential to inform the management of field trial and subsequent deployments of VSM-batteries into the whole system, to support higher levels of convertor-based technology within the GB system than would otherwise be possible.

The project is expected to lead to the development of validated models for one approach to VSM control of batteries. The approach to testing and implementation of that approach clarified such, that industry will be able to take forward deployment.

It is recognized that batteries are one of several technologies capable of deploying VSM or other relevant Grid supporting solutions being sought. This project is intended to act as a template for future larger scale innovation.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

This project will be successful if it has demonstrated whether:

- Inverters can be modified and used to allow inverter connected assets to provide services traditionally provided by synchronous assets generation, e.g. inertia and black start.
- A battery system installed at the Power Networks Demonstration Centre can successfully demonstrate the application of this technology to give confidence to the ESO that this is approach could be used to support system security.

Project Partners and External Funding

Project Partners – The University of Strathclyde, BELECTRIC.

External Funding – (nil)

Three further non- funded partners are also included within the project:

- Scottish Power Energy Networks shall input into the specification of tests conducted and maximize learning between this project and broader activities associated with exploring emergency restoration.
- UK Power Networks shall input into the specification of tests conducted with a particular focus towards performance compatible to distribution connected VSM-controlled batteries
- Scottish Power Renewables have expressed an interest in taking forward the output of the project, subject to satisfactory performance being identified. They would separately identify and commission the PNDC to conduct further tests as relevant to inform the physical specification of a device and explore potential Field trial deployment.

Finally:-

- General Electric & Fraunhoff ISE are supporting BELECTRIC in the control design and modelling of the solutions to be tested and practically deployed. This ensures the work is both relevant to practical commercial deployments and consistent with international developments

Potential for New Learning

The project will provide insight in the following areas-

1. The project will validate at a modelling level the performance of an innovative control system against a structured series of performance tests,
2. New performance test standards will be developed specific to the new areas of performance being demonstrated,
3. New understanding over the design and specification of physical VSM- Battery solutions,
4. A new process template for how future new stability supporting technologies can be developed, evaluated and demonstrated. This can then inform how the implementation of these technologies is managed,
5. New understanding over how VSM performs will be able to support for a Battery based approach moving into field trials.

Scale of Project

The outputs of this project could be applied to any inverter-connected asset in the GB electricity system.

Technology Readiness at Start

TRL4 Bench Scale Research

Technology Readiness at End

TRL6 Large Scale

Geographical Area

The outputs of this project would be relevant to all of GB.

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

£275,000

Project Eligibility Assessment Part 1

There are slightly differing requirements for RIIO-1 and RIIO-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RIIO-2 / RIIO-1).

Requirement 1

Facilitate the energy system transition and/or benefit consumers in vulnerable situations (Please complete sections 3.1.1 and 3.1.2 for RIIO-2 projects only)

Please answer **at least one** of the following:

How the Project has the potential to facilitate the energy system transition:

n/a

How the Project has potential to benefit consumer in vulnerable situations:

n/a

Requirement 2 / 2b

Has the potential to deliver net benefits to consumers

Project must have the potential to deliver a Solution that delivers a net benefit to consumers of the Gas Transporter and/or Electricity Transmission or Electricity Distribution licensee, as the context requires. This could include delivering a Solution at a lower cost than the most efficient Method currently in use on the GB Gas Transportation System, the Gas Transporter's and/or Electricity Transmission or Electricity Distribution licensee's network, or wider benefits, such as social or environmental.

Please provide an estimate of the saving if the Problem is solved (RIIO-1 projects only)

Deployment of VSM technology on inverter connected generation could reduce increases in balancing cost of the order of £300m/year at scale.

Please provide a calculation of the expected benefits the Solution

Lower consumer costs than would otherwise have been the case

A previous VSM project (NIA_NGSO0004), which looked at simulating VSM in the lab environment, estimated £300M/Year net financial benefits to customers. The figure is the annual cost of constraining synchronous generation on and converter fed generation off to reduce the penetration of converter fed generation. It was calculated from the IET paper "System Strength Considerations in a Converter Dominated Power System" which stated a cost of £100/MWh with a constraint limit of 75% and a cost range of £229M - £1099M. However, the earlier project (NIA_NGET0106) indicated that the constraint limit was only 65% which would increase constraint costs. This project will demonstrate the technology described in previous projects and so is contributing to the realization of this financial benefit.

Please provide an estimate of how replicable the Method is across GB

Within the next 10 years, the Future Energy Scenarios published by National Grid ESO estimate that between 3-8GW of batteries that could be connected, all of which would be appropriate for VSM technology to be included. Beyond this, the learning from this project could also be applied to other inverter connected technologies such as solar and wind.

Please provide an outline of the costs of rolling out the Method across GB.

These costs would be uncovered if present in completion of this project and/or in subsequent field trials of the method. As discussed in the project description, the proposed VSM approach is not believed to result in significant additional costs to the developer.

Requirement 3 / 1

Involve Research, Development or Demonstration

A RIIO-1 NIA Project must have the potential to have a Direct Impact on a Network Licensee's network or the operations of the System Operator and involve the Research, Development, or Demonstration of at least one of the following (please tick which applies):

☑ A specific piece of new (i.e. unproven in GB, or where a method has been trialled outside GB the Network Licensee must justify repeating it as part of a project) equipment (including control and communications system software).

☐ A specific novel arrangement or application of existing licensee equipment (including control and/or communications systems and/or software)

☑ A specific novel operational practice directly related to the operation of the Network Licensees system

☐ A specific novel commercial arrangement

RIIO-2 Projects

☐ A specific piece of new equipment (including monitoring, control and communications systems and software)

☐ A specific piece of new technology (including analysis and modelling systems or software), in relation to which the Method is unproven

☐ A new methodology (including the identification of specific new procedures or techniques used to identify, select, process, and analyse information)

☐ A specific novel arrangement or application of existing gas transportation, electricity transmission or electricity distribution equipment, technology or methodology

☐ A specific novel operational practice directly related to the operation of the GB Gas Transportation System, electricity transmission or electricity distribution

☐ A specific novel commercial arrangement

Specific Requirements 4 / 2a

Please explain how the learning that will be generated could be used by the relevant Network Licensees

Both SPEN and UKPN inputs allow the learning on VSM implementation to be applied across the whole electricity system allowing connection at both transmission and distribution voltages to be informed by this work.

Or, please describe what specific challenge identified in the Network Licensee's innovation strategy that is being addressed by the project (RIIO-1 only)

This project informs and impacts the following ESO innovation strategy areas:

- Managing volatility in a low inertia system
- Enabling more non-synchronous connections

☑ Has the Potential to Develop Learning That Can be Applied by all Relevant Network Licensees

Is the default IPR position being applied?

☑ Yes

Project Eligibility Assessment Part 2

Not lead to unnecessary duplication

A Project must not lead to unnecessary duplication of any other Project, including but not limited to IFI, LCNF, NIA, NIC or SIF projects already registered, being carried out or completed.

Please demonstrate below that no unnecessary duplication will occur as a result of the Project.

There is no precedent for the development of specification for VSM and its associated testing on a battery. This will be the first time such work has been undertaken.

If applicable, justify why you are undertaking a Project similar to those being carried out by any other Network Licensees.

n/a

Additional Governance And Document Upload

Please identify why the project is innovative and has not been tried before

There is no international precedent for the specification of functional requirements for grid supporting technologies that could be used to inform VSM testing. As such the systematic approach of test and model validation against a specification relevant to a VSM.

Relevant Foreground IPR

n/a

Data Access Details

n/a

Please identify why the Network Licensees will not fund the project as apart of it's business and usual activities

As no project has been taken forward in a compliance project using VSM for a given technology, no Grid code requirement for testing and demonstration exists for the performance of VSM at present. No project has been taken forward using VSM towards a compliance testing environment as the risk of failing against those compliance tests factor against speculative development. The tests demonstrating VSM go beyond current areas of compliance testing and need to be explored in a collaborative environment where it is safe to fail. This does not fit with BAU activity and R&D is needed to facilitate breaking this barrier as technology solutions come forward.

Please identify why the project can only be undertaken with the support of the NIA, including reference to the specific risks(e.g. commercial, technical, operational or regulatory) associated with the project

Commercial Whilst an NGESO 'Pathfinder' (https://www.nationalgrideso.com/insights/network-options-assessment-noa/network-development-roadmap) project exists to explore the potential requirements for stability requirements across the Scottish area of the transmission system, there are no clear commercial avenues for remuneration of grid supporting capabilities identified. This area can be informed by this project illustrating the trade-offs in performance and capability between normal operation and specification and VSM design and operation, and in the capabilities and opportunities for benefit present from VSM deployment. This learning also complements being able to practically accommodate non-conventional solutions to operability areas such as stability and black start over time. Technical At present the key tests to demonstrate technologies are delivering grid supporting performance and not reducing or removing performance undesirably are not defined. These tests can only be defined in a testing environment which is "safe to fail". This project also supports exploring capabilities beyond that specification informing broader opportunities of service and benefit. Operational Ahead of delivery upon the whole system the performance of new technology needs to be suitably understood and approximated in models supporting planning and operation. This projects simulation workstream delivers improved confidence in this area. Regulatory By involving Transmission, Distribution, User, manufacture and developers collaboratively across the project we can across regulatory areas deliver an integrated whole system view of the benefits and requirements of the VSM technology.

This project has been approved by a senior member of staff

☑ Yes