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 2015

Project Reference Number

NIA_NGET0161

Project Registration

Project Title

Detection and control of inter-area oscillations (DACIAO)

Project Reference Number

NIA_NGET0161

Project Licensee(s)

National Energy System Operator

Project Start

October 2015

Project Duration

3 years and 1 month

Nominated Project Contact(s)

Ben Marshall

Project Budget

£300,000.00

Summary

It is proposed that the project follows the stages of investigation listed below:

- WP1.1. Scoping and Literature review.
- WP1.2 Identification of Modal behaviours Utilising Phasor Measurement Units (PMUs)
- WP1.3 characterising the Modal behaviours and overall control space.
- WP2.1 Application of analysis techniques to detect the risk of onset of inter-area modes.
- WP2.2 Development & prototyping of an analysis tool to detect the risk of onset of inter-area modes
- WP 3.1 Control system design & review.
- WP 3.2 Assessment of possible control system approaches.
- WP 3.3 Identification of those techniques to be applied to the GB transmission system to enable the specification/identification of the right control approaches.

Third Party Collaborators

University of Warwick

Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

Problem Being Solved

An inter-area oscillation on the GB network has been seen at times between England and Scotland, with a frequency of about 0.5Hz. It is managed by using transient stability programs like DigSilent and the power system stabilisers and other controllers of existing plant on the system have been designed so as to provide a damped response to this inter-area oscillation. As noted in National Grid's System Operability Framework (SOF), Synchronous Generation will inherently respond to naturally damp oscillation away from 50Hz given the synchronous torque, related to these machines' inertia which is continuously applied to the transmission system from these power stations. As such, at present it requires an extreme combination of power flow and network depletion scenario to provoke an inter-area mode on the GB Transmission system. As shown in all Future Energy Scenarios (FES) and in the analysis contained within the SOF, as the GB network accommodates greater levels of connection and penetration of Non-Synchronous Generation (for example wind power and HVDC imports from Europe), this reduces the levels of Synchronous Generation available to damp frequency oscillation, and it is expected that further new inter-area oscillations may emerge, for example between Cornwall and East Anglia and that inter-area modes will become more noticeable and dangerous, given the lack of the presence of any corrective action upon the system attuned to these modes. It is essential to detect these before they become serious and to design control strategies that are capable of handling more than half a dozen modes simultaneously.

Method(s)

Detection: Utilising mathematical theories concerning complex perturbation theory and signal identification, we will develop a novel approach founded upon Bayesian methods to identify significant oscillatory signals in phasor measurement unit data and the manner of their evolution. These will be like phonemes – identified in time, frequency and amplitude – but also with a spatial mode structure. We will from this describe the range of control space defined from current network dynamics. The intent of such work will be to construct models, which based on the outputs from Wide Area Monitoring can identify the first signs of new inter-area mode evolution.

Control: Based on the inferred mode structure, we will develop a model for the relevant parts of the electricity network and determine what changes could be implemented to limit the oscillations. We will examine a variety of designed and responsive control approaches that might be applied to power electronic controllers and seek to develop a flexible approach capable of responding to multiple modal behaviours in the future system, including the potential for modes as yet unidentified.

Scope

It is proposed that the project follows the stages of investigation listed below:

- **WP1.1. Scoping and Literature review.** The project will identify from available material the various approaches currently utilised in the setting and optimisation of NSG control systems, and benchmark the challenges of inter-area mode identification, risk detection, response and control design based on comparative approaches in related areas. This will be combined with a thorough review of the project outcomes, range of approaches available and the data available to support the analysis.

- **WP1.2 Identification of Modal behaviours Utilising Phasor Measurement Units (PMUs)**, the project will assess the optimal approach or combination of approaches to signal filtering and detection to separate the signal of well damped inter-area modal response from the noise of general frequency behaviour, together with an assessment of its current magnitude and definition of occurrence frequency.

- **WP1.3 characterising the Modal behaviours and overall control space.** The Project will, based on WP1.2 outputs, seek to characterise the emergence of the modes against system behaviour, seeking to identify the relationships these modes may represent and how they may relate to the system state observed. Based on this, the project will make short-term predictions that can be validated from the available monitoring in real-time to validate these behaviours. The Project will then combine this collection of modal relationships into a total control space which can be characterised mathematically.

- **WP2.1 Application of analysis techniques to detect the risk of onset of inter-area modes**. Based on Bayesian techniques the perturbations of the modal relationships characterised shall be considered against the evolution towards undamped behaviours, such that the margins to instability of damping can be defined and the risks identified.

- **WP2.2 Development & prototyping of an analysis tool to detect the risk of onset of inter-area modes**. Based on WP2.1 the Project will seek to translate the analytical approach(es) developed into an approach compatible with real-time assessment, such that accounting for PMU telemetry within the latency of signalling, processing and action it can be demonstrated that it is possible, with any necessary adjustments of method or refinement of algorithm or processing that it is possible to provide a real-time view of the emergent modes upon the system and their respective risk status.

- **WP 3.1 Control system design & review.** The Project shall review current techniques (eigenvalue, Niquist e.tc.) utilized in the optimization of traditional Power System Stabilisers associated with synchronous machine stability, with a view to identifying the analogous approaches to developing damped response in the control systems of NSG. The Project shall review the current state of play with respect to damped response approaches in the control systems of NSG and how this may affect the design of control responses in relation to the collection of model relationships requiring damping consideration as determined in WP1.3 above.

- **WP 3.2 Assessment of possible control system approaches.** Based on the WP3.1 review an optimal selection of control approach or approaches will be determined considering in addition the flexibility of such options to the emergence of further additional

inter-area modes or modal shifting, as the levels of synchronous generation on the system further declines. In the same manner as WP2.2. where new control algorithms are proposed the issues surrounding signal and processing latency will be considered in the selection of method.

- **WP 3.3 Identification of those techniques to be applied to the GB transmission system to enable the specification/ identification of the right control approaches.** Based on the work in WP3.1&WP3.2, the project will identify the optimal approach to analysing new connections to the studied network subject to such modal characteristics such that the effectiveness of a new damping control may be demonstrated, this would extend to the extent of network and control system modelling required to achieve this aim.

Objective(s)

The intended outputs of this project would be:-

- Improved understanding of inter-area mode phenomena
- Development of a method and analysis package capable of identification of existing low magnitude inter-area modes and providing early warning of the onset of their severity
- Appraisal and assessment of control options and the methodologies surrounding their application on the GB transmission system.

Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

Success Criteria

- The detection method identifies oscillatory events that are currently observed
- The analysis approach is able to highlight the risk of any inter-area modes developing
- The control strategy (or strategies) can be demonstrated to have the capability to successfully limit the observed oscillations and approaches to responding flexibly to new modes/ optimally setting the control system at the design side are identified.

Project Partners and External Funding

University of Warwick: MathSys Centre for Doctoral Training.

Potential for New Learning

- DACIAO will, in developing new methods of extracting and understanding existing modal behaviours occurring but currently adequately damped upon the system provide a greater quality of understanding of the future control requirements and complexities of control needing to be addressed as the damping effect of synchronous generation declines in future years.
- DACIAO will in being able to characterise the emergence of modes of concern allow the extrapolation of current system behaviour into Future Energy Scenarios such that the onset, severity and dimensions of future risk exposure may be presented in National Grid's SOF in this area.
- DACIAO will in exploring control philosophy, design and response options to multiple inter-area modes in the future identify the new design, tuning and analysis techniques in ensuring the ongoing satisfactory operation and specification of Non- Synchronous Generation sources within the GB transmission system.

Scale of Project

The project comprises

- 3-year PhD student project is proposed to complement an initial MSC related to WP1.1-1.3 intended to further support the work.
- Periodic supervisory and consultancy support from NGET
- Potential for part-time or short term working within NGET to support the project aim.

Technology Readiness at Start

TRL3 Proof of Concept

Technology Readiness at End

TRL4 Bench Scale Research

Geographical Area

Warwick

Revenue Allowed for the RIIO Settlement

None

Indicative Total NIA Project Expenditure

The indicative NGET NIA budet for the current scope of the project is c.£300k

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)

Solving the problem would facilitate ongoing compliance with the GB NETSSQSS and Grid Code without requiring the constraining onto the system of a minimum level of synchronous generation and/or synchronous compensation. At this stage the risks of such operation are not assessed but could be analogous to the costs, estimated at up to £600m p.a. saved by the NIC project EFCC.

Were additional constraining action not taken, or inter-area modes not identified & mitigated, the resultant impact could be a blackout or partial islanding of the system, which would be subject to Energy Not Supplied costs. These costs are calculated based on the RIIO-T1 ENS costing lost supply at £16k/MWHr, and could, dependent on the scenario giving rise to the inter-area mode be significant in extent

Please provide a calculation of the expected benefits the Solution

Not required for research projects

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

This would be a GB system-wide method,

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

This project is focussed on research investigating the phenomenon of inter-area oscillation and means to detect them. Exploring methods to mitigate this phenomenon are outside the scope of the current project.

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

The learning generated would improve National Grid (as GBSO) and DNOs approach in the specification of future damping control arrangements for NSG as Synchronous Generation levels decline. The learning will also improve the design of TO assets (specifically HVDC, SVC and STATCOM assets where POD approaches may be applied to support the damping of inter-area modes). This learning could further improve the national specific application of ENTSO-e RfG and HVDC codes within GB, subject to their commitology.

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 addresses the SOF challenges of controlled damping to system incidents, meeting items X and Y of our innovation strategy.

☑ 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.

The project goes beyond what is currently being done with Imperial College (optimal use of HVDC damping control in offshore Wind connections) and with University of Manchester (Supergen project) which are concerned with the plant principles of control rather than theoretical aspects of inter-area mode occurrence, evolution, detection and multi-modal control as discussed above. We are not aware of any similar projects currently underway in UK or elsewhere in the world. Further, there is no overlapping between this work and work currently contemplated under national or European code review.

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

n/a

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

n/a

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

n/a

This project has been approved by a senior member of staff

☑ Yes