

## NIA Project Registration and PEA Document

### Date of Submission

Feb 2014

### Project Reference Number

NIA\_NGET0106

## Project Registration

### Project Title

Control and Protection Challenges In Future Converter Dominated Power Systems

### Project Reference Number

NIA\_NGET0106

### Project Licensee(s)

National Grid Electricity System Operator

### Project Start

October 2013

### Project Duration

3 years and 1 month

### Nominated Project Contact(s)

Jiebei Zhu

### Project Budget

£364,000.00

## Summary

The project will address several inter-linked issues, including: power system characteristics and performance ("system strength") under high penetrations of converter-interfaced sources and HVDC links; investigation of potential future problems under such scenarios; development of solutions for control and protection of such radically-changed power networks. Recent experience and extrapolations from the Irish Power system has highlighted the presence of a "75% barrier" in terms of level of converter-interfaced generation penetration. The innovation outputs are expected to explore key factors towards enabling raising the barriers up to 90%.

### Nominated Contact Email Address(es)

box.so.innovation@nationalgrid.com

## Problem Being Solved

The specific issues to address are as follows:

- Decreasing synchronising torque and first-swing stability (inertia) of the power system due to converter-interfaced sources.
- Potential lack of "system strength", and the effects of converters during unbalanced faults.
- The impact of strength-related effects and converter interfaces on protection system performance (e.g. specific issues around impulse starters, possible issues with waveform distortion on fault detection and discrimination, etc.).
- How harmonics (and unbalance) will increase in future, and how they can be controlled and/or absorbed.

## Method(s)

### Research

Two PhD studentships are proposed for this project. Both students will initially focus on building understanding and simulation skills to enable the performance of the system under a range of future converter-dominated scenarios to be accurately characterised. Following on from this, one of the students will concentrate on the area of converter control and response of converter-interfaces to

system transients, exploring ways in which converters can be made more “grid-friendly” across the range of studied scenarios.

Focused on increasing synchronising torque, the other student will concentrate on the system protection aspects, examining specifically the effects of converter dominated generation systems on existing protection schemes, and the potential for novel protection schemes to address identified problems. Both students will be part of a complementary team, with requirements, constraints and solutions from each side being considered by both parties throughout the studies. They will be part of a large existing team of researchers and academics. While the envisaged activities and deliverables are as described below, these may change during the project to ensure that the end result is a holistic viewpoint consistent with the findings of both researchers and the wider team.

NGET’s input to problem specifications and provision of specialist engineering support, data and validation of outputs is critical. It is envisaged that in the later stage manufacturers of converters & protection systems will be coupled

For the student focusing on converters, the main activities will be:

- 1) Characterisation of system performance under a variety of future scenarios – with a focus on overall system and individual converter responses to a range of events under different levels of converter-penetration.
- 2) Investigation of incremental changes to existing “conventional” converters (i.e. dq-based inner-current-loop controlled with PLLs) which might make them capable of providing inertial responses, and/or enhanced fault ride-through and fault-current responses.
- 3) Investigation and demonstration of more radical non-standard converter control algorithms such as “Virtual Synchronous Machines”, which could potentially provide inertia, synchronising torque, harmonic (and unbalance) mitigation, and useful fault current output, even during unbalanced faults and in networks with arbitrary impedances such as cable- connected networks (where reactive power infeed is not the correct response). This investigation could span both dynamic electrical effects at very short time steps, but also higher-level costs/benefits/constraints implied by such implementations, due to over-rating required and/or energy storage required at the DC bus or elsewhere.

For the student focusing on protection, the main activities will be:

- 1) Characterisation of system performance under a variety of future scenarios – with a focus on LCC and VSC responses to balanced and unbalanced system faults. This will require investigation and development of representative high resolution models of VSC and LCC type converters capable of reproducing instantaneous values (over the required time steps of interest) of currents and voltages in response to both symmetrical and unsymmetrical faults.
- 2) Using the developed high fidelity converter models, conduct an investigation into the performance of transmission system protection schemes under a variety of high converter penetration scenarios.
- 3) Investigate, develop and demonstrate alternative and novel protection methods that are resilient to wide variations in fault level, are sensitive to very low fault currents and can cater for the anticipated changes to waveform shapes and distortion levels that may arise during faults on converter-dominated systems.

## Scope

The project will address several inter-linked issues, including: power system characteristics and performance (“system strength”) under high penetrations of converter-interfaced sources and HVDC links; investigation of potential future problems under such scenarios; development of solutions for control and protection of such radically-changed power networks. Recent experience and extrapolations from the Irish Power system has highlighted the presence of a “75% barrier” in terms of level of converter-interfaced generation penetration. The innovation outputs are expected to explore key factors towards enabling raising the barriers up to 90%.

## Objective(s)

The innovation outputs are expected to cover following aspects:

- a) Environmental & Strategic: to facilitate greater percentage of renewable power generation in GB power system.
- b) Reliability: to ensure stable operation with different generation mixes, and fit for purpose transmission protection functions into the low carbon future.
- c) Connection: to contribute to avoid block on renewable connections, to avoid a hard limit on renewable power development

from a system technical point of view.

d) Commercial: to contribute to avoid constraining renewable power development in the low carbon future and reduce cost from billions to lower hundreds of millions of pounds per year in constraints due to system technical reasons.

## Consumer Vulnerability Impact Assessment (RIIO-2 Projects Only)

n/a

### Success Criteria

The project's success can be measured against the following specific deliverables:

1) Representative and validated models of VSC and LCC converters suitable both for system

stability (e.g. first swing stability) and protection performance analysis.

2) Establish confident model and studies of GB system with up to 75% NSG, applying NGET's proposed means of improving frequency stability (optimised synthetic inertia & fast response) and steady state voltage support (in regions with absence of generation in merit)

3) Describe key limiting factors of operation with even higher percentage NSG beyond 75%, such as:

- a. Synchronising torque inadequacy.
- b. LCC-HVDC converter commutation.
- c. Protection reinforcement for transmission system.
- d. Quality of Supply

### Project Partners and External Funding

The University of Strathclyde are the suppliers for this project.

There is no external funding being brought to this project.

### Potential for New Learning

Through this project increased knowledge will be potentially gained in the areas and scenarios outlined below.

- Decreasing synchronising torque and first-swing stability (inertia) of the power system due to converter-interfaced sources.
- Potential lack of "system strength", and the effects of converters during unbalanced faults.
- The impact of strength-related effects and converter interfaces on protection system performance (e.g. specific issues around impulse starters, possible issues with waveform distortion on fault detection and discrimination, etc.).
- How harmonics (and unbalance) will increase in future, and how they can be controlled and/or absorbed.

The knowledge of the project will be disseminated on the ENA's Smarter Portal, [www.nationalgrid.com/innovation](http://www.nationalgrid.com/innovation), this project is also likely to produce papers that will be published in relevant national and international journals. In addition the learning from this project will be shared in industry focused conferences and with academic forums.

### Scale of Project

Two PhD studentships are proposed to address the outlined issues, one in the area of power system stability and control, and the other in the area of power system protection. Although both inter-linked the two areas are very distinct in terms of required specialised knowledge and expertise, and both elements are seen as potential barriers to the successful achievement of future "gone green" generation mix scenarios. This work will be completed in a laboratory / desk based study.

### Technology Readiness at Start

TRL2 Invention and Research

### Technology Readiness at End

TRL4 Bench Scale Research

### Geographical Area

This project will deliver in Strathclyde.

### **Revenue Allowed for the RII Settlement**

Zero

### **Indicative Total NIA Project Expenditure**

£364,000

## Project Eligibility Assessment Part 1

There are slightly differing requirements for RII0-1 and RII0-2 NIA projects. This is noted in each case, with the requirement numbers listed for both where they differ (shown as RII0-2 / RII0-1).

### 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 RII0-2 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 (RII0-1 projects only)

Unknown - the low inertia issue has not occurred before, but would pose large costs if it did, estimated at a minimum of £1m due to the disruption.

#### Please provide a calculation of the expected benefits the Solution

Not Applicable - Research Project

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

This work will affect the whole of the GB transmission system.

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

This work will be rolled out as part of the project via learning embedded within the business through relevant technical experts. The learning will be shared as already stated.

### Requirement 3 / 1

Involve Research, Development or Demonstration

A RII0-1 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

RII0-2 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 outcome shared by licensee and all stakeholders through expended update of Grid Code which will have an impact on all network licenses. The knowledge of the project will be disseminated on the ENA s Smarter Portal as well as on [www.nationalgrid.com/innovation](http://www.nationalgrid.com/innovation). This project will also be disseminated through relevant national and international conferences and industry and academic forums.

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

n/a

☒ 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.

Following a review of the ENA portal, National Grid can confirm that this work has not been done before.

### 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