NIA Project Annual Progress Report Document

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.

Network Licensees must publish the required Project Progress information on the Smarter Networks Portal by 31st July 2014 and each year thereafter. The Network Licensee(s) must publish Project Progress information for each NIA Project that has developed new learning in the preceding relevant year.

Date of Submission

Jul 2024

Project Reference Number

NIA2_NGESO023

Project Progress

Project Title

Inertia Measurement Method Optimisation

Project Reference Number

NIA2_NGESO023

Project Start Date

September 2022

Project Duration

2 years and 1 month

Nominated Project Contact(s)

Anna Blackwell

Scope

- Understand the accuracy of the inertia monitoring systems and dependencies on different generation / demand profiles.
- Understand regional differences of inertia.
- Establish standardisation methodology for measuring inertia and RoCoF.
- Clarity on accuracy of inertia measurement will feed into specification for inertia products with both Control and planning timescales.

Objectives

Using the metering data from the two new inertia system tools developed following earlier innovation and IT projects, along with the existing NGESO inertia “estimate” and operational data, the project will:

- Analyse and verify the quality of the data from these new tools through comparisons to the existing NGESO estimation.
- Establish different scenarios / use cases for inertia and RoCoF, for example based around levels of synchronous and renewable generation and demand.
- Compare the different solutions based on the established use cases.
- Identify regional inertia variations and representations.
- Develop measurement parameters and specification for reference instrumentation.
- Build on data and use cases to establish standardisation for inertia measurement by comparing measured results to modelling.

Success Criteria

The following will be considered when assessing whether the project is successful:

- The project delivers against objectives, timescales and budgets as defined in the proposal
- Verification of the innovative real-time inertia monitoring solutions
- Deeper understanding of how different generation scenarios impact the inertia on the network

- Deeper understanding of regional inertia variations across GB
- Standard methodology developed and documented for assessing inertia measurements

Performance Compared to the Original Project Aims, Objectives and Success Criteria

National Grid Electricity System Operator ("NGESO") has endeavoured to prepare the published report ("Report") in respect of Inertia Measurement Method Optimisation, NIA2_NGESO023 ("Project") in a manner which is, as far as possible, objective, using information collected and compiled by NG and its Project partners ("Publishers"). Any intellectual property rights developed in the course of the Project and used in the Report shall be owned by the Publishers (as agreed between NG and the Project partners).

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The following paragraphs describe the project progress to date, completed deliverables and next steps for each work package.

Work Package 1: Analysis and comparison of inertia measurements from commercial systems

May 2023: Available data from the real-time commercial inertia measurement systems has been compared with ESO inertia estimations and other power system data to provide an initial plausibility assessment of the commercial products. The behaviour of the inertia monitoring systems during different power system conditions such as high/low wind scenarios and transitions in the level of inertia associated with transmission connected synchronous generation has been analysed. Two interim reviews have been completed with presentations of results to date. The analysis and comparison is ongoing as new measurement data becomes available.

May 2024: Analysis and comparison of inertia measurement results from the two commercial systems has continued over the past 12 months, including all data available for 2023 as well as data from early 2024. The following aspects were analysed in detail:

Potential factors influencing differences between measured inertia values and ESO estimations including correlation to time of day, day of week, time of year, share of non-synchronous generation, level of demand, and inertia level.

Propagation of inertia measurement confidence intervals to predictions of the rate-of-change-of-frequency (RoCoF) for large loss of infeed event.

Quantification of short-term variability of inertia measurements, analysis of factors that increase/decrease variability such as inertia level, demand, non-synchronous generation, and frequency variation.

Four further interim reviews with presentations of analysis results have been completed by the project consortium between June 2023 and March 2024. Drafting of the final report for WP1 is in progress.

Work Package 2: Assess regional differences in frequency and RoCoF for the GB power system

May 2023: Using the reduced 36-bus model of the GB power system, simulation studies have been completed to evaluate the extent of regional differences in frequency and rate-of-change-of-frequency (RoCoF) in historical and future scenarios. The results indicate that under transient conditions, short-term (<1 second) differences may occur between frequency and RoCoF in different locations, and differences are significant with respect to measurement accuracy. Furthermore, the sensitivity of local RoCoF to variations in regional inertia has been studied and found to be significant over timescales less than 500 milliseconds based on the simulation outputs. Two interim reviews of results have been held and the final report is being written. Simulation results will be compared with field measurements when available.

May 2024: The final report for WP2 was completed in June 2023.

Work Package 3: Development of reference framework for inertia measurement verification

May 2023: A set of use cases and measurement requirements for frequency, RoCoF and inertia has been identified and documented. Based on the use cases, a validation methodology has been drafted. NPL is adapting its measurement methods in accordance with the identified use cases to provide robust reference values for frequency and RoCoF under transient system conditions. The next step is to finalise and collate the above content into a framework for submission to standards development organizations.

May 2024: NPL has completed work on the development of a reference method to provide robust reference values for frequency and RoCoF under transient system conditions. The method is based on empirical mode decomposition (EMD) that is successfully removing the oscillation modes and phase steps to determine the underlying grid frequency due to inertial response immediately after generation loss events. The method has been documented as part of a framework protocol that specifies the rationale and implementation of the inertia measurement verification process, mainly centred around the detection and processing of power system events detected using the developed onsite measurement instrumentation.

Work Package 4: Development of reference instrument for inertia measurement verification

May 2023: Real-time implementation and testing of the measurement methods from WP3 on NPL's instruments is in progress. A technical specifications document has been drafted. The next step is completion of the algorithm implementation and calibration of instruments against national standards of AC voltage and current.
May 2024: The development of reference instruments was completed by September 2023 in time for onsite installations (see WP5 below). The instruments have been refined to register candidate power system events when measured rate-of-change-of-frequency (RoCoF) exceeds a specified threshold. Automated consolidation of the measurement data streams from multiple instruments has been implemented to distinguish system RoCoF events from local excursions caused for example by normal power system switching operations. Three instruments have been setup at NPL labs in London, Glasgow and Huddersfield to verify time synchronization, remote access, and measurement data processing. All units are recording frequency and RoCoF in real-time as well as other standard phasor measurements. For each event, the underlying waveform measurement samples are captured with high resolution in addition to real-time frequency and RoCoF values, to allow reproducibility and further investigations of the measurement results. The software has been configured to provide daily event reports. Further software has been written to analyze frequency event data using the EMD method.

Work Package 5: Onsite demonstration of inertia measurement verification using NPL reference instruments

May 2023: Contact has been made with Transmission Owners to arrange installation of NPL's instruments in several network locations. The next step is finalization of specific sites and installation dates.
May 2024: Progress on installation of NPL instruments in high-voltage substations has been slower than anticipated due to the need to complete additional compliance testing. The first instrument was installed in North Scotland in November 2023 and has been streaming frequency and RoCoF measurement data as well as waveform data for specific events. Further instrument installations in South Scotland and across England are expected to complete by end of July 2024.
In the meantime, the validation methodology developed in WP3 has been trialed using reference measurements of frequency events from the instrument installed in North Scotland and from instruments connected to the low-voltage network at NPL sites in London, Glasgow, and Huddersfield.
A review meeting of interim validation results was held in May 2024. The validation work will continue as measurement data from more locations becomes available.

Required Modifications to the Planned Approach During the Course of the Project

May 2023: No modifications required.

May 2024: The project plan intended dissemination of project outputs to the IEC as standardization inputs. The IEC has been approached, however, standardization for power system inertia measurement has not yet been initialized. As an alternative, the outputs will be disseminated to CIGRE Working Group C2.45 which will publish a Technical Brochure on 'Estimation, evaluation and provision of power system inertia in networks with a high share of renewable generation' which is expected to serve as a foundation for further standardization work.

Lessons Learnt for Future Projects

May 2023: To date, the planned methodologies have been effective in completing project activities and deliverables. Therefore, there are currently no lessons to report.

May 2024: Future projects should anticipate that setting up data access and installation of non-standard software packages can take several months. Contingency should be allowed for delays in installation of instruments in high-voltage substations.

Note: The following sections are only required for those projects which have been completed since 1st April 2013, or since the previous Project Progress information was reported.

The Outcomes of the Project

To date, the project has led to the following outcomes:
1. Assessment of the plausibility of results from commercial inertia measurement systems with respect to existing inertia estimation. Identification of scenarios in which measured and estimated inertia have smaller/larger divergences.
2. Assessment of the extent and effect of regional differences in frequency, its rate of change and inertia in the GB power system. Once validated, the results may be used to plan regional inertia monitoring requirements and optimize local frequency management.
3. Use cases and measurement requirements for frequency, its rate of change and inertia have been documented. This information may be used to review existing and specify new requirements for response times of frequency services.
4. Methodology for validation of inertia measurements has been developed. This includes a method for reference measurements of the RoCoF due to inertial response to loss of large infeed events. The methodology provides a framework to assess the extent to which inertia measurement results from commercial systems meet the requirements of the main use case of predicting the frequency

trajectory after large disturbances.
5. Initial validation results based on reference measurements have been obtained and are providing initial insight into absolute accuracy of the commercial systems measurement results.

Data Access

Details on how network or consumption data arising in the course of NIA funded projects can be requested by interested parties, and the terms on which such data will be made available by National Grid can be found in our publicly available “Data sharing policy related to NIC/NIA projects” and www.nationalgrideso.com/innovation.

National Grid Electricity System Operator already publishes much of the data arising from our NIC/NIA projects at www.smarternetworks.org. You may wish to check this website before making an application under this policy, in case the data which you are seeking has already been published.

Foreground IPR

The following outputs will be owned per IPR arrangements between ESO and NPL:

- Methodology and interim presentations of analysis and comparison of inertia measurement results
- Methodology, presentations and final report on investigation of regional differences in frequency, RoCoF and inertia
- Documented use cases and requirements for frequency, RoCoF and inertia measurement
- Validation framework and reference measurement method
- Technical specification for reference measurements