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.

# NIA Project Annual Progress Report Document

## Date of Submission

Jul 2023

## Project Reference Number

NIA2_NGESO033

# Project Progress

## Project Title

Co-optimisation of Energy and Frequency-containment services (COEF)

## Project Reference Number

NIA2_NGESO033

## Project Start Date

January 2023

## Project Duration

1 year and 6 months

## Nominated Project Contact(s)

Colin Webb

### Scope

This project will develop a novel software tool, integrating mathematical models previously investigated to achieve co-optimisation of energy and frequency control services. The tool will link the technical and temporal characteristics of different services, as well as spatial variations in frequency across the network, with the goal of operating the national electricity grid more cost effectively.

The prototype tool will be developed and tested through engagement with the ESO Balancing Programme and a roadmap for future development into a fully operational model within the Control Room will be produced.

### Objectives

- Define the required capabilities and characteristics that the software tool developed should meet for compatibility with control room practices.
- Develop a working prototype software tool to co-optimise energy and frequency-containment services.
- Complete testing of the prototype software tool in coordination with control room engineers.
- Define the needs and requirements to evolve the prototype software tool into a fully operational tool for future integration into the control room.

### 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.
- Novel software tool developed to use mathematical models to achieve co-optimisation of energy and frequency-containment services.
- Fully tested prototype of software tool, including evaluation of capabilities and performance by ESO control room engineers.
- Clear roadmap for further development to achieve an operational tool in the control room.

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

This project aims at developing a tool to co-optimise energy requirements and frequency response requirements. Aiming at reducing the overall cost to the consumers. The project is planned to be delivered through the following four work packages:

**Work package 1 – Definition of capabilities and requirements (completed)**

Imperial College modelling team will engage with the ESO Balancing Programme team to agree the required capabilities and characteristics that any software tool developed should meet for compatibility with control room practices and workflows.

**Deliverable:** A short report on the definition of capabilities and requirements for the software tool

**Work package 2 – Development of working prototype**

In this work package, a working prototype software tool will be developed, designed to enable enhanced operation of the national electricity grid by co-optimising energy and ancillary services. This tool will account for the technical characteristics of thermal generators and energy storage, as well as spatial frequency variations between England and Scotland. This work package will be delivered in multiple tasks:

- Task 2.1: Develop the energy balancing software tool considering demand and RES forecasts, as well as technical characteristics of generators and energy storage. The software will include a feature for Locational Marginal Pricing from the regional network topology.
- Task 2.2: Incorporation of frequency-security constraints for co-optimisation of energy, inertia, and fast and slow frequency response.
- Task 2.3: Enhancement of the model to include new frequency control services, including multi-speed response and optimal largest loss.
- Task 2.4: Incorporating spatial aspect on frequency control such as regional differences in England and Scotland.

Each software version developed throughout these tasks will be validated with relevant sensitivity analysis.

**Work package 3 – Prototype testing**

This work package will cover extensive testing of the prototype software tool developed in WP2, in coordination with control room engineers Deliverable: Prototype software tool for co-optimisation of energy and ancillary services

**Work package 4 – Definition of requirements for fully operational software tool**

This final work package will define the needs and requirements to evolve the prototype software tool into a fully operational tool which can be integrated into the control room if project delivery is successful.

**Deliverable:** A report on the roadmap to integrate a fully operational tool into the control room.

**Project Progress:**

The project is progressing as planned. The first deliverable of the project (Work Package 1) has been completed, and a report detailing the definition of the software tool capabilities and requirements has been shared with the ESO.

Deliverable 1 report details the definition of capabilities and requirements of the co-optimisation tool which include:

- Time-Coupled Unit Commitment (UC) Model - the software tool optimises schedule /commitment and operation of each unit and determines the level of system inertia that is needed to maintain frequency stability at minimum costs
- Dynamic-Frequency Requirements - the constraints associated with Rate-of-Change-of-Frequency (RoCoF), Nadir, and quasi-steady-state requirements are included in the model, which determines the dynamic frequency control requirements
- Value of Inertia - the co-optimisation model can quantify the value of inertia including provision of “synthetic inertia” from inverter-based resources
- Co-optimisation of DC with Inertia and Primary Frequency Response (PFR) - the software tool co-optimises energy delivery and provision of all frequency regulation services and system inertia at minimum whole-system costs, while maintaining energy balance and frequency stability
- Optimisation of Interconnector Outputs to Reduced Largest Loss - the software tool is able to optimise the interconnection power imports and exports in order to minimise the total system operation costs while maintaining frequency stability
- Co-optimisation for both Low and High Frequency Security - the software tool is extended to include the scheduling requirements for both low and high frequency constraints
- Extend the model to include reserve requirement - scope of the software tool is enhanced to model reserve provision from generators, demand-side response and energy storage units, which meets the system reserve and frequency stability requirement while minimising the system operation costs
- Modelling transmission network constraints - transmission network constraints are introduced in the co-optimisation model via DC optimal power flow, which can optimise the provision of energy and frequency regulation services, while managing transmission network congestions cost effectively.

- Extend the COEF model to include N-1 contingencies - software tool will be enhanced to include consideration of N-1 contingencies and determining preventive control actions while minimising the total system operation costs
- Distinct Regional Frequencies - software tool will be extended to account for the spatial variations in post-fault frequency dynamics
- Synthetic inertia - software tool will consider the synthetic inertia from various resources, while the recovery effects will be precisely modelled

The project is currently focusing on developing a prototype of the co-optimisation tool. The relevant data and knowledge required to achieve the tasks set out within work package 2 and develop the prototype have been shared by the ESO project team.

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

The provision of adding reserve services to the project original scope of co-optimising the energy and frequency response requirements has been discussed with Imperial College team. This, in theory, would provide higher savings and reduce the overall cost to the end consumers compared to the current sequential procurement.

The Imperial College team has confirmed that the task of incorporating reserve services to the original project scope should not have a material impact on the project budget or timeline.

No further modifications to the planned deliverables, timelines, or cost are planned or required at this stage of the project.

## Lessons Learnt for Future Projects

Initial analysis has demonstrated significant benefits of coordinating frequency regulation services and energy delivery, while considering changes in system inertia. Detailed analysis of the potential benefits is planned in the upcoming work packages. A full list of lessons learnt will be published when the project is completed.

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

The project outcomes so far include major enhancements to the Co-optimisation tool this includes:

- Over 500 generators with comprehensive Unit commitment parameters (e.g., MNZT (Minimum Non-Zero Time), MZT (Minimum Zero Time), etc.) have been incorporated into the co-optimisation model.
- All frequency-related constraints have been included in the tool for co-optimisation of Energy and Frequency (COEF) - Rate-of-Change-of-Frequency (RoCoF), Frequency Nadir, and quasi-steady-state requirements.
- Frequency services related to inertia, primary frequency response (PFR), dynamic containment (DC), the influence of dynamic regulation (DR), dynamic moderation (DM), and the optimised largest power infeed/outfeed are involved in the co-optimisation model.

- The interconnectors power flows (power import and export) are optimised in the model to minimize the whole-system costs are included to model the largest power infeed or outfeed, depending on its status of power import and export.
- The model is now capable of capturing the influence of demand-side inertia.
- Requirements for both Low and High Frequency Security have been included in the COEF model.
- Operating reserve requirements have been included in the COEF model.
- Work on incorporation transmission network constraints and line outages in the COEF model has started.
- The influence of considering frequency-related constraints on operation cost and computing time is analysed. Under most cases, the computing time can be limited within 15 minutes.
- The influence of minimum inertia limit is studied.

## 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/SIF projects on the Smarter Networks Portal  (www.smarternetworks.org) and National Grid ESO Data Portal (data.nationalgrideso.com). You may wish to check these websites before making an application under this policy, in case the data which you are seeking has already been published.

## Foreground IPR

The following are expected to be delivered by this project:

- Open-source tool, codes, data and tool documentation.
- Short report on definition of capabilities and requirements for the software tool to be developed.
- Final report on the tool performance and roadmap to fully operational tool.

As the first deliverable has been concluded the following report will be uploaded to the Smarter Networks Portal when available:

- Short report on definition of capabilities and requirements for the software tool to be developed.