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NIA Project Annual Progress Report Document

Date of Submission

May 2025

Project Reference Number

NIA2_NESO073

Project Progress

Project Title

Future Operator Console: Optimised Visualisations

Project Reference Number

NIA2_NESO073

Funding Licensee(s)

NESO - National Energy System Operator

Project Start Date

November 2024

Project Duration

2 years and 1 month

Nominated Project Contact(s)

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Scope

NESO is working to develop the Operator Console Project to deliver an innovative way to streamline data and information to aid operator decision support. This project will provide an analysis of overview visualisations and associated 'design principles' that can be applied to the control room. It will consider academic concept and test against current and future data sets, while also potentially providing opportunities to validate ongoing work. It is a desktop study looking at the science of visual perception and the control room design for enhanced operational awareness in future energy scenarios.

Objectives

- To assess current control room (CR) methods and the influence of known visual factors and the limits on the CR visuals.
- Evaluate visualisation alternatives for the CR and provide recommended guidelines and designs that can improve visual comprehension and decision-making for CR tools.
- Generate and document synthetic zero carbon simulation data for case studies to consider for operational conditions.

Success Criteria

The project's success will be measured by its ability to achieve the objectives, through:

- Understanding around current visualisations on where they are not contributing to situational awareness and proactive behaviour and recommendations on how they can be improved
- Recommendations on how visualisations can be used to enhance operational awareness (visual comprehension and decision-

making) in future energy scenarios in the control room.

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

National Energy System Operator ("NESO") has endeavoured to prepare the published report ("Report") in respect of Future Operator Console: Optimised Visualisations, NIA2_NESO073 ("Project") in a manner which is, as far as possible, objective, using information collected and compiled by NESO 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 NESO and the Project partners).

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The project aim is to provide an analysis of overview visualisations and associated 'design principles' that can be applied to the control room, considering academic concepts and testing against current and future data sets, while also potentially providing opportunities to validate ongoing work.

There are three objectives:

1. To assess current control room methods and the influence of known visual factors and the limits on the control room visuals.
2. Evaluate visualisation alternatives for the control room and provide recommended guidelines and designs that can improve visual comprehension and decision-making for control room tools.
3. Generate and document synthetic zero carbon simulation data for case studies to consider for operational conditions.

During the first 8 months of the project (out of a total of 24), two reports were delivered on schedule and within budget, with the third report due at the end of month 9.

1. **The first report**, delivered at the end of month 3, set out the control room context and provided an outline of the current visualisations used on NESO's videowall at the Electricity National Control Centre (ENCC). It detailed applicable use cases for the current arrangement, which are intended to be used as example tasks and scenarios for evaluating visualisation alternatives during the remainder of the project.

This report provided a review of relevant academic literature to the project, first giving an overview of the perceptual and cognitive mechanisms that contribute to how data visualisations are interpreted by the human visual system. It then explored how power systems have been visualised previously within the academic literature. From this review, it was concluded that very few prior studies have considered:

- a) factors relating to the physical viewing environment of the control room, and
- b) how our understanding of the human visual system can inform guidelines for visualisations on large videowall displays in the energy system context.

These insights are critical to the first and second objectives outlined above, and the report concluded by resolving to address this gap.

The first report also described how simulation data will be generated during the project by using a synthetic power grid system with a representative geography and network layout. Simulation data will be generated and used to construct scenarios of relevance to the identified case studies, which in turn will be used for the evaluation of visualisation alternatives. This description, together with ongoing activities, contributes to objective 3.

2. **The second report**, delivered at the end of month 6, focused on visual acuity, which refers to how individuals can make out fine details of visual elements on a display or within a broader visual field. It described how the human visual field comprises of regions with varying densities of photoreceptors within the retina, with the central foveal region being the densest and therefore the area with the

highest visual acuity. It provided a calculation for estimating the number of pixels required to match the density of photoreceptors in the retina and concluded that the current pixel density of the videowall display at intended viewing distances in the ENCC was in rough alignment with the bandwidth of the human visual system (resulting in project guideline 1).

Three guidelines (project guidelines 2,3, and 4) were then proposed based on known limits of visual acuity for normal and corrected-to-normal vision. The guidelines proposed minimum sizes for points, lines, and text on the videowall display to ensure perception of these visual elements from different viewing distances in the ENCC.

The report went on to consider two further parts of the visual field outside the foveal region: the parafoveal region, which is effective for pattern recognition, and which can inform the maximum size of possible data visualisations (project guideline 5), as well as the peripheral region, which can be utilised by the visual field for tasks such as the identification of visual alerts in the control room. These five guidelines contribute to objective 1 in respect to the limits of control room visuals and to objective 2 by providing recommended guidelines based on empirical evidence from the literature. Furthermore, they demonstrate how guidelines in the project will be delivered in future reports.

The second half of report 2 outlined the design of a Virtual Reality Control Room for evaluating visualisation guidelines, which is a modification in approach from the original project plan (described in further detail below). It also outlined an initial experiment design to compare responses from alternative visualisations, enabling the evaluation of visualisations, as described in objective 2. This experiment is being designed to evaluate detection, perception, and interpretation of system alerts, taken from a use case identified in the first report. In the experiment, there will be three competing visualisation designs: Status Quo, using the existing control room visual encoding and the visual alerts; Alternative 1- greyscale with coloured alerts; Alternative 2: greyscale with newly proposed extensible alert glyphs, initially incorporating visual encodings for alert severity and alert type. The experiment will be conducted using a virtual reality headset and multiple-choice questions within the headset will be used to assess the participant's interpretation of the visual alert. Eye-tracking functionality will also be used to track the gaze of the participant.

3. The third report will focus on the topic of visual salience and provide recommendations and guidelines on designing visualisations that can attract the visual attention of control room operators. While the project is still in its early stages, the work completed to date demonstrates significant progress towards the project's success criteria of a) providing recommendations to improve existing visualisations in the control room and b) towards the design of control room visualisations for future energy scenarios.

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

One modification to the planned approach is in the adoption of virtual reality technology to build a virtual control room for evaluating visualisation designs. A justification of this change in methodology was provided in the second deliverable report. In summary, the benefits provided by the use of virtual reality include the ability to incorporate elements of the control room (such as the correct physical dimensions, focal distances, and lighting) within the evaluation procedure, thereby improving ecological validity of the proposed experiments. Furthermore, virtual reality provides greater experimental control, providing the experiment designers full control over the participants' visual field. Costs associated with the use of virtual reality include the additional development time for experiment development and the additional acquisition of a high-end head mounted display for running the experiments. It is expected that the development of the virtual control room is feasible within the timescale of the project, however it may mean that empirical results of visualisation evaluation may only become available during the second half of the project. Nevertheless, we expect that these results to be more ecologically valid (i.e. more applicable to control room settings) due to the use of virtual reality. The additional financial costs for technology are currently intended to be borne by the university.

Lessons Learnt for Future Projects

At this early stage no lessons learnt have been identified yet.

Interim project outcomes:

- A shared understanding of relevant control room case studies and a description of the visualisation context.
- Review of relevant perceptual and cognitive elements of the human visual system and how this might relate to visualisation design in the context of the control room.
- Review of power system visualisation approaches in the academic literature.
- Five guidelines relating to visual acuity of control room operators with normal or corrected-to-normal vision.
- A justification for the use of VR in evaluating visualisation alternatives for the control room, as well as an overview of key components for the construction of the virtual control room.

- Outline experiment design to evaluate visualisation alternatives for the task of detecting, perceiving and interpreting system visual alerts.
- A proposed extensible glyph design for visualisation of substation state and possible visual alerts.

The two reports delivered to date (WP1 and WP2) are available for GB licensed energy networks to access upon request.

Review of benefits case:

The intended benefits of the project are a significant improvement in speed and accuracy of situational awareness and decision-making within the control room and the facilitation of pro-active decision-making. The research is also expected to have long-term potential in the reduction of training costs by having a clearer interface.

The guidelines delivered to date can inform the design of future control room visuals, with alternative visualisation designs already proposed by the project. These alternative visualisations will be empirically validated through experimental work during future stages of the project, and it is our intention to provide quantitative empirical evidence of these benefits.

The adoption of virtual reality technology for evaluating visualisation alternatives in the control room provides another pathway to the reduction of training costs since it may be viable for NESO to utilise the virtual control room during training scenarios.

Next steps:

The project is continuing according to its original workplan, providing reports and visualisation guidelines on each of the topics shown in table 1 below.

The project is also continuing in the development of a virtual control room for evaluating visualisation alternatives, with an experiment planned on the detection, perception and interpretation of visual alerts on the videowall display, as described above. We hope to undertake our first experiments during Autumn 2025.

<u>Primary Topic Area</u>	<u>Due Date</u>
WP1 Control room methods and case study development	Complete
WP2 Visual Activity	Complete
WP3 Visual Salience	30/05/2025
WP4 Colour	29/08/2025
WP5 Annotations and contextual information including faults, missing data and uncertainty	28/11/2025
WP6 Decision making with visual alternatives	27/02/2026
WP7 Screen-size effects	29/05/2026
WP8 Advanced factors, such as peripheral vision and dual-target costs	28/08/2026

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

Two project reports have been delivered, which are available on request for GB licensed energy networks. Due to ongoing invention and research within the project the TRL level is currently unchanged (TRL2: Invention and research).

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 NESO can be found in our publicly available “Data sharing policy related to NIA projects (and formerly NIC)” and [Innovation | National Energy System Operator](#).

National Energy System Operator already publishes much of the data arising from our NIA projects at www.smartemetworks.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

- Report on current control room methods and case study development
- Visual acuity study investigating the relevant perceptual and cognitive elements of the human visual system and how this might relate to visualisation design in the context of the control room.