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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 Close Down Report Document

Date of Submission

Dec 2024

Project Reference Number

NIA2_NGESO004

Project Progress

Project Title

Trial on Implementation of Wide Area Monitoring and Control System (WAMCS)

Project Reference Number

NIA2_NGESO004

Funding Licensee(s)

NESO - National Energy System Operator

Project Start Date

September 2023

Project Duration

1 year and 0 months

Nominated Project Contact(s)

Jay Ramachandran & Tim Pinto

Scope

This project will explore the implementation of the WAMCS communication/execution hardware by running a non-operational trial. A WAMCS prototype would be established on the GB electricity transmission network. It would be physically trialled by using the existing communication infrastructure. This non-operational demo trial will not instruct active power response so the trial would not affect the real-time system operation.

The WAMCS will be installed in the ENCC. Communication links will be established between the WAMCS and the PMUs/market participants so that the WAMCS can receive the PMU measurement data and send control instructions to the market participants. We will also develop the security and communication requirements for implementing the WAMCS in the GB system.

Communication latency is critical to the version of WAMCS as it affects how quickly the control action can be initiated. This project will measure the communication latencies at different stages in the WAMCS. This learning would be valuable to various WAMCS applications, such as network split prevention protection, oscillation control, etc. Moreover, the response of the WAMCS to different system events will be investigated.

This will be the first time such a WAMCS has been installed on the GB network, and the project will also provide valuable knowledge on how to fit the WAMCS in the CNI environment, which has yet to be explored previously. The project will consist of 5 main work packages:

- WP1 – Design
- WP2 – MCS Development

- WP3 – MCS Deployment
- WP4 - Demonstration
- WP5 – Reporting and Knowledge Sharing

Objectives

The objectives of the project are to:

- Establish the connectivity between the TOs' PMUs and the ESO PDCs to understand PMU accuracy and communications performance requirements for wide area monitoring and real time data acquisition.
- Install the WAMCS consisting of RA, CS and LC in the ENCC CNI environment and establish communication links to market participants via LD.
- To monitor the performance of the WAMCS system and understand solution latency on current infrastructure.
- To validate the response from WAMCS for different system events.
- To ascertain the technical aspects for potential response providers to connect to a wide area control system.
- Training for internal/external stakeholders.

Success Criteria

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

- The WAMCS prototype is established, which receives PMU data from SPEN PDC to ESO PDC.
- The WAMCS logic correctly identifies the system event and sends a response instruction to the market participants.
- A project report is delivered on time, which details:
    - Architecture and design of the WAMCS, and communication requirements to obtained TO PMU data and send instructions to market participants.
    - The costs of implementing the WAMCS and the associated communication links.
    - The performance of the WAMCS, in terms of latency, correct coordination and discrimination with different level of PMU data quality and communication quality.

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

Project Overview

This project aimed to explore the implementation of the Wide Area Monitoring and Control System (WAMCS) communication/execution hardware through a non-operational trial. The WAMCS prototype intended to be physically tested using the existing communication infrastructure wherever possible. The key enabler of WAMCS is Phasor Measurement Units (PMUs) installed by the Transmission Owner (TO) that communicate data back to the NESO for use in wide area control and other applications. The MCS intended to identify frequency events based on PMU data and estimate the real power balance required, communicating this to various service providers. However, this project intended to only conduct a non-operational demonstration without any actual power changes. Upon deployment, the scheme will undergo functional testing and latency assessment of the wide area control commands, aiming to meet the NESO target of 0.5 seconds from measurement to control command. In this demonstration, number of changes have been made to accommodate the trial due to the security constraints and time limitation and are explained in the later sections.

Project Plan and Work Packages

The project is divided into five work packages (WPs):

WP1 – Design

Objectives and Achievements:

Statement of Work (SoW): Completed and agreed upon by all partners.
Access Requirements: Documented and addressed, allowing for remote project execution with local support.
Hardware and Software: All necessary components ordered and received.
Training: Three days of training provided by GE Digital to the NESO project team.
The design phase established a modified, centralised version of the regional frequency control scheme developed under the EFCC project. The deployment at NESO's Data Centre includes multiple Phasor Controllers (PhCs), issuing commands to remote sites via a secure IPsec (Internet Protocol for secure connections between devices) tunnel. The design work was successfully completed, setting the foundation for future WAMCS activities within NESO.

WP2 – MCS Development

Objectives and Achievements:
PhC Development: Developed functionality allowing PhC connection to the NESO IPsec tunnel.
EFC Logic Development: Modified logic for the Local Device and Central Supervisor, enabling the EFC demonstration.
MCS Trial Run: Prepared and executed trial runs within GE offices, producing a draft report on outcomes.
Latency Monitoring: Developed a solution for monitoring the latency of asynchronous connections.
The EFC logic development, connection requirements, and latency measurement protocols were successfully established. All items in this work package have been completed.

WP3 – MCS Deployment

Objectives and Achievements:
Data Forwarding: Changed PMU data transmission from aggregated to forward streaming to minimize latency.
Deployment: Installed MCS equipment at various sites and conducted basic testing.
Data Collection and Archiving: Enabled GE to receive and archive trial data from SPEN and NESO devices.
Local Device Deployment: Deployed redundant Local Devices at GE offices.
The project successfully deployed local devices and the MCS system at the Data Centre. Communication links between PMUs and the Phasor Data Concentrator (PDC) were updated for forward streaming, laying the groundwork for the demonstration.

WP4 – Demonstration

Objectives and Achievements:
Non-operational Demonstration: Tested the MCS system with emulated PMU data, generating various scenario datasets.
Communication Link: Established the link between SPEN PDC and NESO PDC.
The non-operational demonstration began in Q2 of 2024-25 and tests have been carried out for different scenarios. The MCS system functionalities have been tested for the following cases (A) Ramp rate (B) Synthetic data generated from PowerFactory tool (c) Simple oscillations to the data (d) Loss of PMU data. In this demonstration, the latency between different components have been captured.

WP5 – Reporting and Knowledge Share

Objectives and Achievements:
Outcome Reporting: Key outcomes, lessons learnt, and requirements for future implementations are documented.
Deployment Reports: Brief reports on deployment and decommissioning are produced to inform future MCS projects.

Conclusion and Next Steps

The project has successfully designed the Wide Area Monitoring and Control System (WAMCS) architecture, to deliver the frequency response service. Figure 1 in attached appendix shows the architecture, for PMU data transfer to the NESO PDC through SPEN Transmission Owner PDC. This architecture is placed within CNI environment and the required firewall settings have been carried out by the DD&T team within the NESO. PMU data from SPEN PDC to NESO PDC is transferred using forward streaming method, rather than aggregated streaming method used in monitoring projects.

Figure 2 in the Appendix shows the MCS system arrangement installed in a Data Centre. The MCS system comprise of 4 PhC; Central Supervisor (CS), Regional Aggregator (RA) and 2 x Local Controller (LC). Due to the security constraints, the developed MCS system was not installed in the Critical Network Infrastructure (CNI) environment. For the purposes of this trial, the developed MCS system is installed in a Data Centre.
The Emulator streams the synthetic PMU data in to the MCS system and from the perspective of the MCS this data appears to be real PMU data from a WAMCS. The MCS system processes this data to identify the frequenc=y event. If a frequency event is detected, the MCS system sends a signal to the Local Devices (LD). The communication link from Data Centre to LD locations, through IPsec tunnel, are established through this project. For this trial purpose, LDs are installed at the NESO Warwick office location and GE Office at Edinburgh.

This project successfully installed all the components required for the trial and established the required communication links and firewall arrangements. GE Vernova provided and tested the MCS system configuration, the required components and software to be installed in the system to carry out the tests. GE also provided training to the NESO SMEs on the Phasor Controller, PDC components and the relevant software. GE also carried out the functional testing of the scheme deployed for the non-operational demonstration.

The project carried out 29 cases and verified the functions of the MCS system deployed and measured the latency. These tests were carried out for different system inertia conditions (82 GVA-s and 130 GVA-s) as well as different RoCoF threshold levels (0.25 Hz/s, 0.3 Hz/s so on). The MCS configuration has been tested for the following variants:
1. Inertia level of the system
2. The amount of generation / demand loss in the system, that leads to different RoCoF values
3. Threshold RoCoF limit settings
4. PMU data availability
5. Oscillation Conditions and different ramp rate scenarios

When there is a frequency event, but the RoCoF value is lower than the threshold value, MCS system correctly identified this and correctly did not trigger the resources, as expected. When there is a frequency event and RoCoF value is sufficiently above than the threshold RoCoF limit, the MCS system correctly identified the event and triggered the service providers to respond to the event. For certain scenarios, the rate of frequency change is below the threshold value but is sufficiently sustained that the system frequency reaches 49.2 Hz. If this is the case, the MCS system responds and triggers the service providers and provides fixed power output to balance the power generation and demand, when the frequency reaches the lower limit of 49.2 Hz. In this trial it has been assumed that when less than 80% of PMU data is available, the MCS system will not respond i.e., the confidence level is set as 80%. In the trial it has been tested that with less than 80% of PMUs available the MCS system does not trigger or responded. Note, the threshold confidence level can be configured by the user and would typically be reduced as the total number of PMUs is increased. The MCS system fails to trigger when the system RoCoF value is closer to the RoCoF threshold values, due to the detection methodology used. Hence, the threshold RoCoF limit settings should be selected appropriately for the implementation. Furthermore, this insensitivity band could be reduced by applying a refined trigger design that applies a set of filter windows instead of one window. The trial demonstrated that the developed MCS system/ EFC configuration works as expected for different scenarios.

The latency between the following components have been added up to get the total latency:
1. SPEN PMU to SPEN PDC
2. SPEN PDC to NESO PDC, using forward streaming method
3. Stream forwarding within NESO environment in Data Centre
4. MCS system detection time
5. MCS system to Local Device

The overall latency time, from the time frequency event occurs to the command signal received by the Local Device at the service providers' sites are calculated. The typical latency of 420ms has been achieved in the trial, which is within the target of 500ms latency. This trial also identified number of further changes in the design that could reduce the latency further by 60 ms to 100 ms. In the trial, the percentage of data loss between LC to LD locations is less than 3%, for the selected trial periods.

This trial proved that WAMCS could be a potential solution for the future frequency response service. This project has made significant progress in implementing a WAMCS prototype, paving the way for future advancements in wide area monitoring and control within the NESO IT environment. This project also identified the changes required in the architecture, EFC scheme and components required for the successful implementation of this scheme.

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

Due to IT security risks, the monitoring and control system (MCS) system has been installed in a Data Centre environment, rather than the Critical National Infrastructure (CNI) environment. Hence the latency is measured in two stages; one is from PMU to NESO Phasor Data Concentrator (PDC), through SPEN TO PDC. The latency of communication was assessed as two separate components:
Latency between selected PMUs in Scotland to NESO Phasor Data Concentrator (PDC), and
the latency from the emulator and the MCS in Data Centre to the Local Device
These components were evaluated separately and added together. This method still provides the complete latency details.

Due to the data confidentiality and security requirements, PMU data received by the NESO PDC in CNI environment can't be transferred to the Data Centre, for this project. Hence, an Emulator has been built in Data Centre to send the synthetic PMU data to MCS system. However, the Emulator environment provided opportunity for the project team to test for different scenarios, different frequency events that may not be possible to test in the real system event.

The project originally planned to have two service providers sites to locate the Local Device. However, due to the limitations of service provider participants in the non-operational demonstration, two office locations are considered as service provider sites. This change does not affect the tests or performance of the developed WAMCS, as this project is only non-operational demonstration (no active power change from service providers is expected).

Due to the age of EFCC logic relative to existing GE software and hardware, it was not possible to transfer the EFCC logic to the new hardware and software used for the trial. Hence new logics have been developed and tested for most of the EFC components. During the testing, the Phasor Controller (PhC) software / logics have been updated with the learnings from the trials.

Lessons Learnt for Future Projects

- The centralised WAMCS approach has been developed, and this method could be used when EFC style frequency control is required for the production in future.
- RA, CS and LC could be built as one virtual Phasor Controller that could reduce the latency values further whilst also simplifying deployment and maintenance.
- For this demonstration purpose, 8 PMUs were available, and all of these PMUs are M-type. The latency within M-type varied with the location of the PMU and manufacturers of the PMU. To further reduce latency, low latency PMUs should be selected for the future implementation. With the P-type PMUs, instead of M-type PMUs, latency could be further reduced. For the WAMCS applications, P-type PMUs would be recommended to reduce the latency.
- The Local Device (LD) design and the components required have been researched for this trial. The device had connectivity challenges due to the mobile connection. For the stable operation, uninterrupted internet connections are required. The data flow from MCS system to LD also had unexpectedly high data transfer in this project. These elements need to be further investigated before the future implementation.
- The learning on firewall and port requirements for the forward streaming methods will be used for future implementation of this solution.
- In the trial, MCS system was installed in a Data Centre due to the security constraint to place the MCS system in CNI environment. Learnings around requirements for deploying the MCS system in the CNI environment have been gained and could be used for future deployment in production. It is recommended to use Emulator for the testing purpose. However, for the deployment of this solution Emulator is not required, as PMU data could be directly fed from NESO PDC to MCS system.
- The project setup was challenging due to the time required for the contract negotiation, in particular topics such as gaining security clearance to work in the CNI environment and delays with multi-party contracting. In this trial, MCS system was placed in the Data Centre due to the time limitations to get the required security clearance. In the future, security clearance requirements need to be planned well in advance to get the specialised personal to get the required access so that full WAMCS could be built in the CNI environment.
- Considerations should be given to the threshold RoCoF limit required, for the given inertia of the system. It is recommended to carry out system analysis for the significant events and identified the required RoCoF threshold.
- Mobile internet connection has lots of fluctuations and disturbance which resulted to disconnection of IPSec tunnel. For stable IPSec tunnel, uninterrupted internet connection should be considered for the Local Device operation.
- It is recommended for phasor controller's network interface should allow adding gateway rather defining gateway in routing page. It is recommended for Original Equipment Manufacturer (OEM) to have Border Gateway Protocol (BGP) protocol support to their product.
- It is recommended for OEM to add features of network bonding/ team and LACP to avoid single point of failure.

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

This is the first project in the GB system successfully demonstrated the WAMCS application, for Enhanced Frequency Control solution. This project successfully delivered the target latency, to trigger the required service responses within 500ms. The MCS system installed at a data centre and Local Devices are installed at NESO office at Warwick and GE office at Edinburgh. Hence the trial system demonstrated the communication link across the GB system and achieved the targeted latency. The project successfully designed the Wide Area Monitoring and Control System (WAMCS) architecture, to deliver frequency response service.
The project has delivered:

- The design requirements of the WAMCS, for the non-operational demonstration of Enhanced Frequency Control (EFC), have been completed and implemented. The installation of MCS systems (RA, LC, CS, LD and Emulator) was completed in the data center.
- The communication link between PMUs from SPEN region to NESO PDC through SPEN PDC has been established. SPEN PDC to NESO PDC forward streaming of PMU data rather than aggregated stream has been established. The forward streaming method reduced the latency compared with the aggregated streaming.
- The WAMCS built in this trial was tested for different scenarios. The test results showed that it is possible to achieve the target latency of 500ms. In these trials, the typical latency of 420ms has been achieved, with the RoCoF threshold setting of 0.3 Hz/s. It is possible to reduce the latency further by selecting suitable PMUs, centralized virtual MCS architecture.
- In this trial, all SPEN PMUs are M-type PMUs. However, the latency from PMUs to SPEN PDC varied significantly with different PMUs. This is to be expected and can be due to the (A) Location of the site such as remote site could lead to larger latency period (B) Manufacturers and/ or design of PMUs. It is recommended to use P-type PMUs for the WAMCS applications, to reduce the latency further.
- The trial also showed that the amount of data loss is less than 3% and this provides more confidence that a scheme deployed in this way would present very few reliability issues due to communication issues or data loss.
- This project provided learnings on components requirements, firewall requirements and port allocation requirements to the future

projects.

- The architecture of the MCS system is designed as centralized system, whereas in the EFCC project decentralised architecture was used. The centralised MCS system was tested successfully and could be used for the future implementation.
- The project team also completed training on PDC design and WAMC applications and this will build the NESO's further capabilities on WAMC system applications.
- This project also provided the learnings on future architecture requirements, EFC components required for the future implementation.

The post fault frequency service Dynamic Containment (DC) is in place, for the GB system, to respond to the frequency events. For the current inertia level and system background, DC could be sufficient. As the practicality of the EFC system has been proved through this project, it can be considered as a future solution if DC and other levers prove to be insufficient. For future implementation, this project provided recommendations on architecture, EFC schemes, PMU types, communication, and firewall requirements.

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 NIC/NIA projects" and www.nationalgrideso.com/innovation.

NESO 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

- Statement of Work document that includes the EFC Design for WAMCS implementation
- Closure report for the non-operational demonstration will be published in Smarter
- Network Portal
- EFC General Report
- EFC Scheme Signal Check List Report
- EFC Latency Report
- DD&T Report on EFC Implementation Guide

Planned Implementation

The post fault frequency service Dynamic Containment (DC) is in place, for the GB system, to respond to the frequency events. For the current inertia level and system background, DC could be sufficient. As the practicality of the EFC system has been proved through this project, it can be considered as a future solution if DC and other levers prove to be insufficient. For future implementation, this project provided recommendations on architecture, EFC schemes, PMU types, communication and firewall requirements.

Net Benefit Statement

This is the first project in the GB system successfully demonstrated the WAMCS application, for Enhanced Frequency Control solution. The project successfully designed the Wide Area Monitoring and Control System (WAMCS) architecture, to deliver frequency response service. This project successfully delivered the target latency, to trigger the required service responses within 500ms.

As the practicality of the EFC system has been proved through this project, it can be considered as a future solution if DC and other levers prove to be insufficient for low inertia system. Through this solution, all types of technologies can participate in frequency control services and that could reduce the cost of system operation.

For future implementation, this project provided recommendations on architecture, EFC schemes, PMU types, communication and firewall requirements. The completion of demonstration provided learnings on quality of PMU data received, latency of the communication, cost involved in establishing the WAMCS logics. During this project training materials on WAMCS logics have been developed and are beneficial to build wider NESO development in this area. The demonstration provided learnings on security requirements for implementing this solution in the future.

Other Comments

The Project outcomes and results contain confidential information and intellectual property rights that cannot be disclosed in this Report due to their proprietary nature. Should the viewer of this Report (“Viewer”) require further details this may be provided on a case by case basis following consultation of all Publishers. In the event such further information is provided each and any Publisher that owns such confidential information or intellectual property rights shall be entitled to request the Viewer enter into terms that govern the sharing of such confidential information and/ or intellectual property rights including where appropriate formal licence terms or confidentiality provisions. Dependent upon the nature of such request the Publishers may be entitled to request a fee from the Viewer in respect of such confidential information or intellectual property rights.

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N/A