Visualisation of Real Time System Dynamics using Enhanced Monitoring (VISOR)

In collaboration with

Project Progress Report

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Table of Contents

1 Executive Summary

SP Transmission (SPT), supported by the other transmission licensees and the academic partner, made a full proposal submission for the project: Visualisation of Real Time System Dynamics with Enhanced Monitoring (VISOR), under the Network Innovation Competition (NIC) mechanism in 2013. Ofgem approved the proposal and issued the Project Direction on the 19th of December 2013. The project commenced in January 2014 and is due to conclude in March 2017.

The VISOR project aims to showcase the role of an enhanced Wide Area Monitoring System (WAMS) in overcoming the challenges facing the GB power system as it moves toward a low carbon future. It has created the first integrated GB WAMS and has also marked the first deployment anywhere in the world of new Waveform Measurement Units (WMUs), which generate 200 frames per second data for the detection of sub-synchronous oscillations (SSO).

The VISOR WAMS is the first to collate, store, visualise and analyse synchronised measurements in real-time across all three of the GB Transmission Owners (TOs). The WAMS incorporates wide area synchronised phasor measurements produced at a rate of 50 frames per second that provide unparalleled monitoring and understanding of the dynamic behaviour of the GB system, when compared to unsynchronised SCADA data that is sampled at one frame per second or less.

VISOR will focus on the following key areas that are expected to be of the most benefit to the GB system in the short to medium term:

- Real-time monitoring and alarming of oscillations in the range 0.002Hz to 46Hz - from low frequency generator governor behaviour, to inter-area oscillations, to sub-synchronous resonance introduced by series compensation and sub-synchronous interaction introduced by power electronic converters,
- The use of WAMS data to aid and enhance post-event analysis and network & dynamic model validation,
- Hybrid state estimation using Phasor Measurement Unit (PMU) and SCADA data, and,
- The potential use of angle based security limits to relieve power flow constraints across the B6 boundary between Scotland and England.

The PhasorPoint and technology supplier for VISOR, Psymetrix, part of Alstom Grid, was acquired by General Electric as of November 2015. The company name has subsequently changed to Grid Solutions: a GE and Alstom Joint Venture (or “GE’s Grid Solutions”) and is referred to as “GE” within this report.

1.1 Project Highlights

This is the fifth progress report and covers six months of the project delivery from January 2016 – June 2016, “the reporting period”.

The project delivery is in line with the original proposal regarding project programme, resources, budget, risk management, intellectual property rights (IPR) and knowledge sharing; and over the reporting period supporting evidence for the following elements contributing to the Successful

Delivery Reward Criteria (SDRC) have been delivered on schedule, with some restrictions as described later in this report:

SDRC 9.2.1

✓ *Applications delivered and configured to include (WP 1.2, 2.3, March 2016)*

- ***Geographic oscillation alert presentation***
- ***Oscillation source location presentation for analysis & real-time***

SDRC 9.6.1:

✓ ***Presentations and show-casing at the annual innovation conferences (WP 5.4, Dec 2014, Dec 2015, Dec 2016 and June 2017 for Close-down report dissemination)***

The following was delivered ahead of schedule in November 2015:

SDRC 9.1.1

✓ *Baseline and comparator report for SSO behaviour (WP 1, March 2015,* ***March 2016,*** *March 2017)**

The Project Delivery Team (PDT) has successfully undertaken the following activities during the reporting period:

- WMU installations have been successfully completed at the following locations:
  - Grain, above the original scope of the project
- Established the following communication links between Data Centres and the Data Hub:
  - SPT-NGET: Multiprotocol Label Switching (MPLS) link between SPT's Phasor Data Concentrator (PDC) at Kirkintilloch and NGET's Data Hub at Wokingham.
  - SHE-NGET: IP-Sec between Perth PDC and Wokingham Data Hub commissioned April 2016.
- Successfully development of two new PhasorPoint applications, *VLF (Very Low Frequency) Oscillation Detection* and *LF Oscillation Source Location Enhancement,* showcased at the Application Demonstration Workshop on 30 March 2016, at GE, Edinburgh.

As a mark of intent, and furthering the use of WAMS technology within the businesses, there are plans to install WMUs in 2016 at the following locations:

- NGET: Deeside/Connah's Quay[1]
- SPEN: Auchencrosh (SPT)

[1] Deeside is in the process of being replaced by a new substation, Connah's Quay, scheduled for completion in 2018, upon which the WMU will be transferred from Deeside onto the new circuits at Connah's Quay.

During the reporting period, knowledge dissemination has focused on key internal stakeholders to continue building support of the application of this technology so that there is ample enthusiasm for future implementation following the conclusion of the project by hosting the following highly successful events:

- Innovation day at Kirkintilloch, February 2016
  Hosted by SP Energy Networks
- Seminars and strategic consultation with PG&E at Kirkintilloch/Glasgow, February 2016
  Hosted by SP Energy Networks
- Interview and engagement process across multiple departments within SPEN, NGET TO and NETSO in Glasgow, Warwick, Wokingham, and via teleconference, April 2016
  Hosted by SP Energy Networks and National Grid.

The SPEN internal intranet and social media portals have been utilised to internally publicise project meetings and engagement with departmental heads and lead engineers.

In addition to the dedicated knowledge dissemination events organised and hosted by the project team, the knowledge gained by the project has been shared with the wider industry through the following activities:

1. Presentation at NASPI Work Group meeting and first International Synchrophasor Symposium, 24th March – 26th March 2016, Atlanta, USA.
2. PAC World Conference, June 7th, Ljubljana, Slovenia
3. Paper and Presentation at CIRED Conference, 14th June – 15th June 2016, Helsinki, Finland

The University of Manchester and GE have submitted the following papers seeking to represent VISOR at key upcoming international conferences:

PSCC Conference 2016, 20th-24th June 2016, Genoa, Italy

- ➢ *Impact of Load Dynamics on Torsional Interactions*
- ➢ *Addressing Emerging Network Management Needs with Enhanced WAMS in the GB VISOR Project*

IEEE PES General Meeting, 17th-21st July 2016, Boston, USA

- ➢ *Placement of SSO Monitoring Devices for Maximum Visualization of Torsional Interactions*

CIGRE Session, 21st-26th August 2016, Paris, France

- ➢ *Advances in Wide Area Monitoring and Control to address Emerging Requirements related to Inertia, Stability and Power Transfer in the GB Power System*

In terms of upcoming knowledge dissemination and sharing events in 2016, the following events will be held or attended by members of the VISOR PDT:

- Dedicated VISOR External Stakeholder Event in London
- Internal stakeholder engagement and training events at the Sandbox facility
- Workshop and Presentation of WAMS use-cases, benefits, investment options and implementation strategies conclusions from the VISOR Roadmap.
- External stakeholder engagement, in particular the dedicated VISOR event and the LCNI conference.
- IEEE General Meeting, 17th-21st July 2016, Boston, USA.
- Cigre Conference, 21st-28th August 2016, Paris, France
- Low Carbon Network Innovation Conference, 11th-13th October 2016, Manchester, UK.

1.2 Project Risks

There are currently no uncontrolled risks that could impede the achievement of any of the SDRCs outlined in the Project Direction, or which could cause the Project to deviate from the Full Submission. We monitor risks on a continuous basis with regular review at monthly progress meetings. The key risks are summarised below, with more details in Section 4.

1.2.1 Technical and Roll-Out Risks

The following technical risks were encountered during commissioning and system analysis for project VISOR in the reporting period:

- **Configuration of data transfer and firewall - Cyber Security (Critical National Infrastructure):** The interactions between Monitoring Devices (PMUs & WMUs), the VISOR TO Datacentres and VISOR SO Data Hub presents security risks. The different companies have different IT policies and security arrangements to protect from external threats. The key challenge is in ensuring that security of national infrastructure is not adversely affected, with the risk being that a mutually acceptable solution will not be agreed between all parties.
- **Configuration of MPLS link between SPT and NGET**: The risk that the link does not perform as desired within the timescales of the project, hindering the ability to conduct meaningful comparative assessments with the IP-Sec link to inform the GB WAMS Roadmap
- **Configuration of test facility:** The new facility is intended to bridge the gap between innovation and Business as Usual (BaU) for all project partners by providing a live demonstration of the integration of WAMS in EMS/DMS applications. The risk is that timely delivery of this facility, in order to successfully demonstrate and undertake training within the environment, will not be achieved.

1.2.2 Project Management Risks

The key project management risks that have been encountered during the reporting period are listed below. Project Managers at each of the project partners have ensured that these risks are continuously monitored and actively managed to ensure the project milestones are not jeopardised:

- **Integration of innovation into business as usual activities:** Uncertainty surrounding the true benefits of phasor information will hinder the roll-out into BaU.
- **Establishing a successful continuation plan:** The ultimate success of the project will be determined by the onward progression into BaU. In order to best position the technology the VISOR project must address the uncertainty of the business case for both TO & SO, the low level of internal experience and confidence in the WAMS technology and applications, and the concern that increased data must not impede other BaU practices.

Further details of Risk Management including Technical Risk and Project Management Risk can be found in Section 4 of this document.

1.2.3 Summary of Learning Outcomes

The main learning outcomes over the reporting period are summarised below,

Pilot: Corporate vs Critical Network

At the beginning of this project the decision was made to establish the VISOR system outside the project partners Critical Network Infrastructure and within the Corporate Networks. This decision was made for a number of reasons, including

- ➢ It is an innovation project with an as yet unproven applicability with unknown requirements and unquantified benefits.
- ➢ By virtue of being an innovation project it was not considered "Business Critical".
- ➢ Company readiness for the technology was low and it may not have been possible to reach an agreement between SPT, SSE, and NGET within a sufficient timescale to install within their respective Critical Networks.

Situating the VISOR WAMS within the Corporate Network was the easier and less time-exhaustive approach and, as stated above, it may not have otherwise been possible to establish the cross-TO system within the strict timescales of the project. This has, however, increased challenges down the line, particularly in relation to Cyber Security.

- Cyber security
  As the original architecture did not have to adhere to the same levels of Cyber Security required for the Critical Network, a key challenge has stemmed from the successes of and interest in the technology, leading to demand for and use by other functions of the business as part of business-as-usual. The demand for this integration is raising complexity and Cyber Security concerns.

The importance and necessity of a Roadmap

The transition beyond a pilot project into the business requires strong evidence and business cases for the deployment of the technology. Some of the largest benefits of the technology may not be realised unless each TO has greater visibility of the wider network outside of their license area. Some benefits may be realised before this point, but these may be harder to quantify, such as the avoidance of catastrophe and asset damage. Benefits for the SO will depend on the monitoring coverage (proper placement of sufficient monitoring devices installed).

The development of the WAMS Roadmap for the GB is a complicated task affecting multiple parties with both benefits for TO's and SO intertwined. The key lesson here is that this particular task has such breadth and significance that it could have formed a standalone work package.

2 Project Manager's Report

This section highlights the VISOR projects' key activities, milestones, risks and learning over the reporting period (January 2016 – June 2016).

2.1 Project Progress Summary

VISOR remains on course for a satisfactory delivery over this reporting period regarding the project programme, with all milestones on schedule and the undertaking of extra initiatives to boost the business readiness following completion of the project as we enter the project's final year.

"The changes in generation on the transmission network, particularly in Scotland, means that the intuition of system behaviour our experienced control engineers have developed over the past 20 years no longer applies. Sophisticated software applications are now becoming crucial to understand and manage the network within the parameters set." Joe Hunter, SPT Senior Control Engineer.

The significant achievements during this reporting period are:

- High-speed, high-reliability MPLS link between Kirkintilloch WAMS "Datacentre" (SPT) and Wokingham WAMS "Data Hub" (NGET) commissioned on 29th February 2016.
- Successful commissioning of WMU at Grain - a site beyond NGET's original scope.
- Two new PhasorPoint applications successfully developed and showcased at the Application Demonstration Workshop on 30th March 2016, at GE Edinburgh:
    - VLF (Very Low Frequency) Oscillation Detection, and
    - LF Oscillation Source Location Enhancement
- Potential sub-synchronous (4-46Hz) oscillatory interaction detected between known (monitored) and suspected (unmonitored) generation plant. This was low-level behaviour, but has prompted investigation as a matter of prudence, to confirm the VISOR observations. This perfectly highlights the benefit of the SSO monitoring being demonstrated by VISOR: the continuous aspect of the VISOR approach enabled this sporadically appearing mode to be detected, and the wide-area aspect provided information for engineers to target their investigation.
- Valuable internal stakeholder engagement involving international experts and with direct deployment experience of wide-area-monitoring using synchrophasors.

<u>Workstream</u>:

- Key additional project initiatives, identified in the previous period, are underway to strengthen the progression into business as usual, including:
    - ✓ The design and creation of a WAMS-EMS integration 'Sandbox' test facility at SPEN
    - ✓ Commissioning the development of a systematic roadmap for the progression of WAMS technology into BaU

  - Kick-off meeting with Quanta Technology held on 29th February 2016 to support the development of a GB WAMS Roadmap
  - First round of WAMS Roadmap interviews undertaken with key personnel from NGET and SPEN between 18th April and 22nd April 2016

- ✓ Development of an independent and supplier-agnostic phasor data processing and visualisation application
  - Contract signed with Open Grid Solutions on 19th May 2016
  - Beta application due in early Q3 2016

- Model Validation studies using the full GB model are underway - the University of Manchester now have access to the National Grid GB model via a NGET workstation.

Knowledge dissemination activities:

- During the reporting period, significant efforts have been made to engage with the wider industry to maximise involvement and learning from international experience of synchrophasor deployment and applications, including:
  - Numerous meetings between NGET and SPEN personnel and Dr. Vahid Madani, Chief Project Manager of Pacific Gas & Electric's $50m Synchrophasor project.
  - Attendance and presentation at the North American Synchrophasor Project Initiation (NASPI) conference.
  - Facilitating interviews and workshops between NGET and SPEN personnel with US-based Quanta Technology, who have vast experience in the deployment of WAMS in the Americas.
- A multitude of VISOR knowledge dissemination and promotion activities to internal and external stakeholders and the wider industry within the UK and overseas, including:
  - VISOR 'Innovation Day' held at SPEN Operational Control Centre, Kirkintilloch on the 5th February 2016.
  - A number of discussions held with SPEN and NETSO Control Room personnel to ensure the needs of the Control Centre are captured and feed through to the WAMS solution.
  - Production of educational videos for knowledge dissemination activities.
  - Enhancements to VISOR website to accommodate the download of previous project progress reports and presentations.
- GE have published the following reports during the period:
  - *200Hz WMU explanation paper*
  - The first of a series of monthly performance reports: these augment the annual VISOR reviews. Regular updates on WAMS performance mean that issues are

highlighted and resolved more quickly. Regular summaries of power system behaviour highlight issues at a time when they can best be investigated – whilst other sources of information, e.g. local substation logging data, are still available and data buffers have not "rolled". This activity also serves to inform roll-out recommendations on business processes for WAMS data – what should be included in reports, how often should reports be generated, etc.

Research and papers:

The University of Manchester have continued their highly valuable input into the project with the following noteworthy contributions during the reporting period:

- Study into Hybrid State Estimation and Sub-Synchronous Resonance completed.
- Workshop presenting and discussing the latest conclusions from the research undertaken at the University on the 2nd June 2016
- The final revision and acceptance of the paper entitled "Impact of Load Dynamics on Torsional Interactions" for the prestigious Power System Computation Conference (PSCC)
- The first revision of the journal paper entitled "A Screening Rule Based Iterative Numerical Method for Observability Analysis" that has been submitted to the IEEE Transactions on Power Systems;
- The submission of the journal paper entitled "Investigation of the existence of a Sub-synchronous Resonance Interaction Band" to the IEEE Transactions on Power Systems.

In addition, GE have supported the following contributions:

- Revision and final acceptance of a further paper for PSCC 2016, entitled "Addressing Emerging Network Management Needs with Enhanced WAMS in the GB VISOR Project"
- Final acceptance of a poster session paper for the Protection & Control World (PAC World) 2016 conference (13-17th June, Ljubljana, Slovenia) entitled "VISOR Project: Initial learning from Enhanced Real Time Monitoring and Visualisation of System Dynamics in Great Britain"
- Revision and final acceptance of a paper for the CIGRE 2016 Session (August, Paris, France), a joint submission with the National Grid "Smart Frequency Control" NIC project, entitled "Advances in Wide Area Monitoring and Control to address Emerging Requirements related to Inertia, Stability and Power Transfer in the GB Power System"

The project is now in its second phase, the *operational stage*, whereby the continuous flow of new data gathered by the project is collated, analysed, and translated into new information on the dynamic behaviour of the system on a wider and more precise scale than ever before.

The new insight gained during this stage will form the basis of the development and justification for implementation into the daily operations of the Network Licensees. To supplement this stage of the project, the PDT have undertaken new initiatives to support this transition, including the provision of a new dedicated demonstration and training facility and a simpler high-level geographical, multi-platform, visualisation tool to demonstrate a potential use case and build confidence in live deployment.

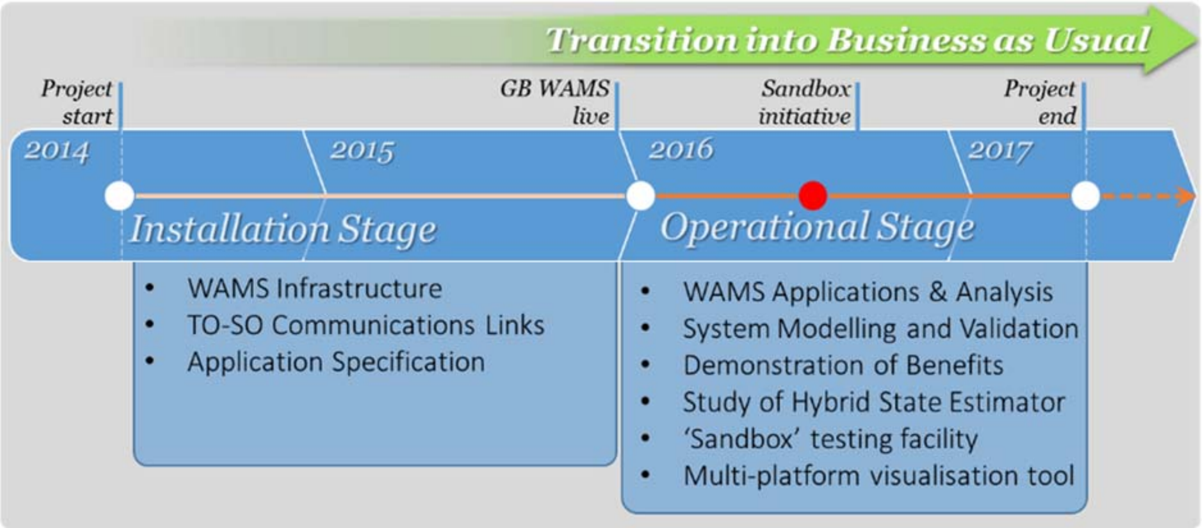


Figure 1. VISOR high-level timeline

2.2 VISOR WAMS infrastructure update

A total of nine "Waveform Measurement Units" (WMUs), three localised *Data Centres,* and one centralised *Data Hub* were originally intended to be installed on the Transmission Network under VISOR to provide synchrophasor measurements and monitor Sub-Synchronous Oscillations (SSO) across GB. To date, ten WMUs have been fully installed and commissioned across GB collecting new data on SSO behaviour in the system. In addition to the above, the University of Manchester has also a WMU for testing.

In light of the new valuable information gathered by this new WMU technology, and a reflection of the business commitment to WAMS, further provisions have been made to purchase additional WMU units to be installed onto the VISOR WAMS. A suitable outage window is required within which the units can be installed and commissioned. An overview of the status of the installed and proposed WMUs locations is provided below in Table 1 and Figure 2.

National Grid have installed two WMUs at newly identified sites, beyond the original scope of the project. The interconnector between the UK and the Netherlands has been identified by NGET where SSO is a potential issue due to interactions when operating HVDC links adjacent to wind-farms and thermal plant. A WMU has been installed at the primary substation, Grain, to further safeguard this.

Similarly, the Western HVDC link between Scotland and England will be monitored using the WMU technology. The commissioning of the WMU at Deeside substation is awaiting an available outage window, expected in Q4 2016. In Scotland, SPT will complete the monitoring of the Western HVDC link by installing WMU monitoring on the circuits connecting the link, at Hunterston, which, when coupled with the WMUs on the other end at Connah's Quay, will provide comprehensive monitoring of the operational behaviour of the high capacity HVDC link.

#	VISOR Partner	Locations (circuits)	Status
4	Scottish Power	Eccles (Stella West 2) Torness (Eccles 2) Hunterston (Inverkip 2, to be Strathaven) Auchencrosh (Coylton)	Installed and operational Installed and operational Installed and operational 2016/17
3	National Grid + one project spare	Hutton (Harker 1) Stella West (Spennymoor 1) Deeside/Connah's Quay (Circuit 1)	Installed and operational Installed and operational Installed and operational
5	above original scope	Hutton (Harker 2) Stella West (Spennymoor 2) Deeside/Connah's Quay (Circuit 2) Grain (Circuits 1 & 2)	Installed and operational Installed and operational 2016/17 1 of 2 Installed and operational
2	Scottish Hydro Electric	Kintore Beauly	Installed and operational Installed and operational
1	The University of Manchester	Manchester	Operational

Table 1. WMU outstation device locations and status

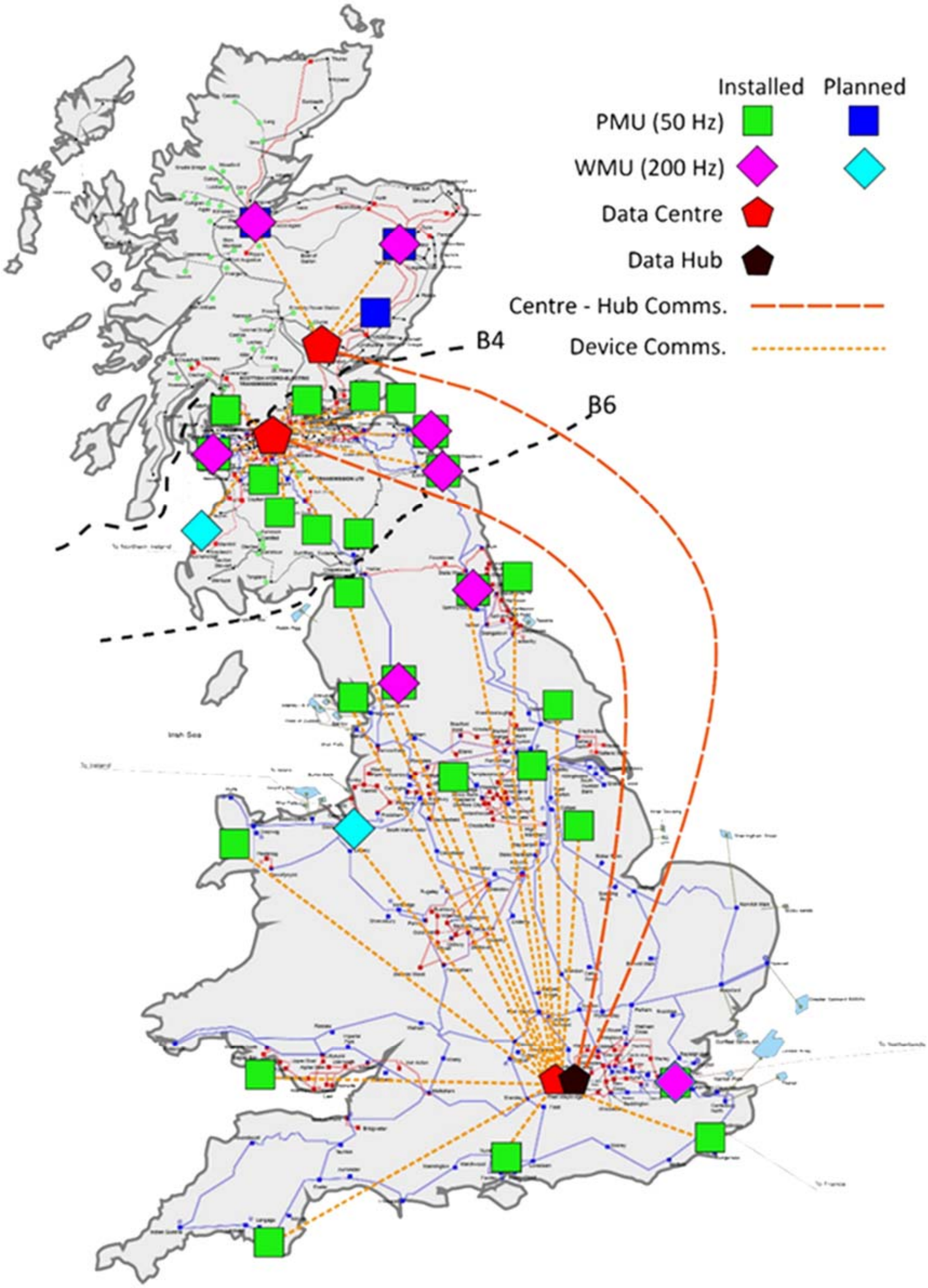


Figure 2 VISOR WAMS Deployment Overview

2.3 Communications infrastructure between TO and SO

A key challenge of the project has revolved around the commissioning of the new communication links between the three transmission network regions.

During this reporting period, both links between SHE-NGET and SPT-NGET have been commissioned:

- The IP-Sec between the PDC at SHE and the Data Hub at NGET was successfully commissioned on 18 December 2015.
- The repeatedly delayed Multiprotocol Label Switching (MPLS) link between the PDC at SPT and the Data Hub at NGET was successfully commissioned on 29 February 2016.

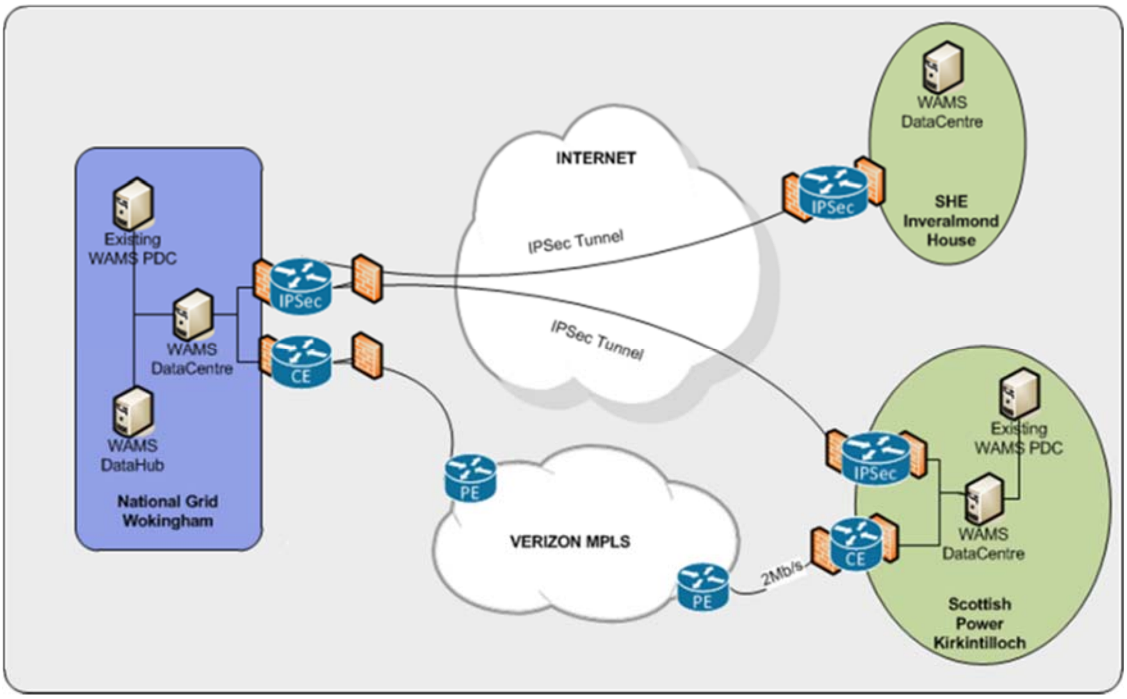


Figure 3. VISOR Communication Links between SHE TL, SPT, NGET and NGET SO

Whilst commissioning the hardware and communications of each outstation monitoring device entails a degree of complexity and management, any delays have been short and inconsequential. However, the communication infrastructure between the PDCs and the Data Hub at Wokingham has presented the most significant challenge, and is a fundamental aspect of the project.

To accommodate the large quantity of new phasor data gathered within SPT under VISOR, a MPLS link was selected as the most suitable medium for data transfer– providing unobstructed data channel from the SPEN Datacentre server to the Data Hub server at National Grid. Given the transfer requirements between SHETL and NGET are comparatively small, a more straightforward and more conventional Internet Protocol Security (IP-Sec) tunnel was more appropriate. There are advantages of each method that have been covered in previous reports but to use an analogy, the MPLS link is a dedicated motorway, whereas the IP-Sec link shares the route with all other traffic.

However, as a mitigation action in response to the delayed MPLS link, an IP-Sec link had to be established.

The MPLS was commissioned on 29th February 2016 however teething problems affecting the communication of data streaming across the link has prevented the full potential of the MPLS link to yet be realised.

Technical teams at both SPEN and NGET are investigating the problems affecting the MPLS performance, which is currently thought to be related to a bandwidth issue resulting in connection resets between the two PhasorPoint servers. The current MPLS bandwidth of 2Mbps is sufficient for PMU and WMU data streaming however, it is insufficient for simultaneous data streaming and historical data recovery transfers. Following a recalculation of the data bandwidth requirements the link is to be increased to 4Mbps.

Given the successful operation over the IP-Sec link, which has lesser reliability and latency capability than the MPLS, this technical issue does not present a direct risk to the project but rather creates some very useful learning for future consideration into the “Production System”.

Once the MPLS issues have been resolved, a performance comparison will be made between the two mediums that will generate useful learning for future implementations. In the event that the IP-Sec proves incapable of handling the large quantities of PMU and WMU data, an assessment into the necessity for all PMU data will be made - allowing the team to determine a selection strategy.

2.4 Visualisation of data in SPT, NGET, SHE TL Transmission including real-time and historic

In the previous progress report (Dec’ 2015) it was highlighted that this milestone had been partially achieved in so much that SHE TL had real-time visibility, for the first time, of phasor information on their network, however, this data was not being transferred onward to NGET in real-time, but rather relied on a manual transfer.

The communication issues that have prevented the live ‘streaming’ of measurement data from SHETL to NGET is still to be resolved, owing to site access and VPN issues. GE are supporting SHETL with this activity and anticipate completion within the coming months.

As also highlighted in the previous report, the proposed MPLS link between SPEN and NGET had suffered numerous delays beyond the control of the PDT and culminated in a contingency plan being executed; an IP-Sec link was established between the parties to allow streaming of live data from SPEN to NGET in order to mitigate the risk of negative knock-on effects to other deliverables.

During this reporting period the MPLS link has been commissioned but is experiencing issues affecting its performance, as discussed above. Once resolved, the MPLS will operate as the preferred communication medium for data transfer between SPEN and NGET, supporting high-speed and highly reliable transfer of data from over 150 individual sources within SPT.

Following the successful completion of the above, the System Operator now has the ability to visualise and analyse synchronised PMU and WMU measurement data in near real-time, as shown in the figure below.

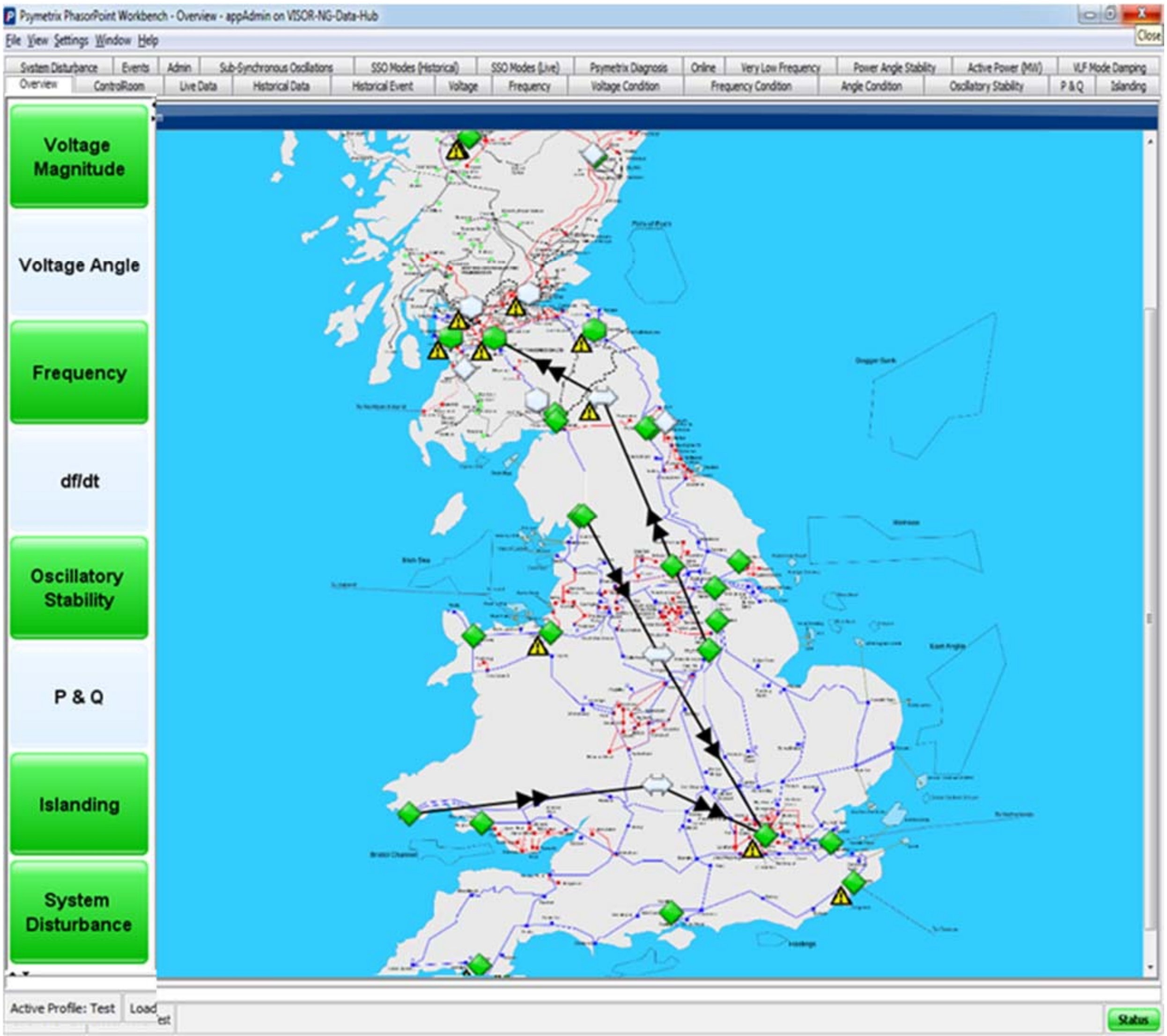


Figure 4. WAMS monitoring across three TO regions

2.5 VISOR WAMS Roadmap

The fundamental purpose of the VISOR project is to demonstrate and develop the implementation of synchronised monitoring technology in order to incorporate and accelerate its integration into the GB electricity supply industry so that it provides benefits that represents value for money for GB customers.

The technological risks are alleviated incrementally throughout the project, as milestones are achieved and exposed problems are addressed. The technology providers are responsible for ensuring their products perform correctly and problems are fixed as required, however, it is the responsibility of the Network Licensee partners to ensure that the products are effective, purposeful, and deliver operational benefit.

The full potential of the VISOR WAMS may not be recognised for many years to come with the adoption of more devices, applications, and supporting infrastructure that may eventually enable sophisticated automatic control and protection of the network. The full-scale GB-wide production-grade system deployment will be a major undertaking, which certainly will require more funding and will take several years of major efforts to complete.

To secure the funding for this effort, it is necessary to clearly identify the business drivers, needs, and the benefits of implementing various synchrophasor applications, including those piloted in the VISOR project to help establish the business case for the capital investment required for such a deployment effort.

The Roadmap is intended to:

- Facilitate the transition from a synchrophasor infrastructure implemented through the VISOR project and previous efforts to an integrated production-grade operation tool to support business-as-usual operations of the GB transmission network – across the control room, analysis, and planning environments.
- Better leverage the already deployed synchrophasor system infrastructure to minimize the additional investment while achieving the desired business and operational goals
- Better coordinate the use of the existing phasor technology and the complementary real-time and planning systems
- Address how synchronized measurement technology can help improve real-time monitoring, protection, automation and control to deal with the increasingly high level of Renewable Energy Resources, and the growing reliability and power quality requirements from customers
- Elicit further consensus among stakeholders on the additional business needs to be supported by the enhanced full-scale production-grade synchrophasor technology deployment
- Obtain buy-in among stakeholders on their business needs to be supported by the synchrophasor technology
- Accommodate post-VISOR project additional PMU installations as necessary and the implementation of additional selected applications that will be identified through the roadmap development process

- Define optimal extensions of the installed base (in terms of infrastructure, applications and processes) to be in concert with SPT and its project partners' stakeholders needs;
- Identify budgetary constraints, corporate goals and preferences; with technology and regulatory constraints with voluntary and cooperative agreements among SPT and its partners
- Facilitate better coordination of the plans with all the involved utilities' area of responsibility.
- Assist management of SPT and its partners in approving further investments required for the full-scale production-grade synchrophasor technology system deployment

Quanta Technology, who have vast expertise and experience in largescale production-grade synchrophasor technology deployment projects across North and South America, have been commissioned to work with all project partners to support the development of a GB WAMS Roadmap, which will form part of the project close-down report.

2.6 New project initiatives

Reliability and stability are absolutely paramount in transmission network operation and planning. The system, and all its parts, are consequently designed and chosen conservatively, with as minimal risk as possible. The introduction of a fundamentally new monitoring system is a non-trivial undertaking and will undergo rigorous review and scrutiny before it can be considered suitable for use.

Establishing a successful continuation plan is one of the most fundamental risks of any innovation project in order for transition into the business. This is amplified in a project with multiple partners involved, such as VISOR; each with independent long-term development and technology deployment and upgrade strategies and policies.

The implementation of this technology is dependent on each company's readiness to realise the potential benefits of this new capability, some of which differs between Transmission Owners and the System Operator. The readiness ultimately stems from a small group of individuals within each organisation who utilise the technology to improve their working practices, which may lead to improved operational efficiency or reduce cost. It is the responsibility of the PDT to demonstrate how, and why, the different businesses would adopt the technology so that the decision to implement can be made.

The PDT recognises the magnitude of the challenge to transition the VISOR WAMS into the daily operation of the businesses, but understand fundamentally what is required by the businesses for roll-out. We have sought to engage with internal stakeholders diligently to ensure their needs are met and concerns addressed and, through the Roadmap and Project Close-Down reports, will strive to demonstrate the tangible benefits that may be realised.

Two new key workstreams have been identified by the PDT to help support the overall objective to progress WAMS into the businesses.

2.6.1 WAMS Integration 'Sandbox' Facility at SPEN

Through VISOR, the project partners have gained new insight into system behaviour through the aggregation, analysis and presentation of PMU/WMU data delivered through the e-terra*PhasorPoint* WAMS platform. Many of the application modules being used are new, seeing their world-first demonstration under VISOR. Workshops and presentations have demonstrated these new applications and the capabilities available to potential end-users of the technology; however, an opportunity was identified to enhance this effort, by establishing a dedicated WAMS integration and testing facility within SPEN.

Whilst VISOR has successfully engaged with key personnel to become pro-active in exploring PhasorPoint, we identified an opportunity to make use of an existing SPEN EMS upgrade environment that would make the VISOR WAMS more accessible for all project partners, enable better training, and bring the system closer to production-grade.

SPEN's EMS upgrade programme included a test environment, located within the Control Centre, primarily for the purpose of trialling, training and completing FAT & SAT tests ahead of deployment of the new EMS into a live environment set to conclude in Q2 2016.

The notion of establishing a testing facility within VISOR has had growing support and following further discussions with Dr Vahid Madani regarding PG&E's proof of concept laboratory, SPEN's Head of Real-Time Systems Strategy & Projects endorsed the plan to re-purpose the EMS environment, once SAT testing had been completed, and create a 'Sandbox' test facility for the VISOR WAMS.

The growing support of the facility signifies the continued backing of the technology but also, as the Sandbox facility would reside within the company's secure Real-Time System (RTS) network, it significantly improves the overall business readiness position as the transitional gap between innovation and business as usual is reduced.

The Sandbox would provide SPEN with the opportunity to directly address the concerns surrounding future integration of new WAMS data into the EMS, *e-terravision*. Given that engineers would require new training for the new EMS system, the timing of the inclusion of WAMS data was highly favourable, and would provide users with greater appreciation of the benefits of the interface between EMS and WAMS, including:

- **Improved situational awareness capabilities**
  e-terra*vision* will be able to show WAMS events and key data within the geospatial visualisation environment
- **Improved data integration**
  e-terra*stability*: Grid Stability Assessment (GSA) will allow WAMS data and oscillatory stability results and alarms to be viewed within **e-terra***browser*
- **New historical analytics tooling**
  The addition of **e-terra***phasoranalytics* can be used in both the new Sandbox environment and the current VISOR systems to provide easy off-line analysis tools and reporting capabilities

The development of a Sandbox EMS-WAMS system does not only facilitate achieving the goals listed above, but moreover, provides a safe environment for exploring and trialling the next generations and phases of WAMS-EMS integration and visualisation capabilities.

The facility is designed to:

- Integrate WAMS data into e-terravision 4.0
- Provide e-terraphasoranalytics 1.2 for enhanced Offline analytics
- Feed WAMS data into state estimation over IEC 60870-5-104
- Alarm sharing and WAMS data visualisation with e-terrastability: Grid Stability Assessment (GSA)

Whilst the facility will be located within the SPEN Control Centre, a series of demonstration and training events will be held to allow representatives from NGET and SHETL to witness the integration of PMU and WMU data.

The proposed architecture of the new Sandbox is shown in the figure below. A more detailed technical description of the facility and the applications provided in Appendix 2; this document is currently under review and awaiting final approval.

The facility is anticipated to be commissioned in Q3 2016 following successful conclusion of the EMS upgrade programme.

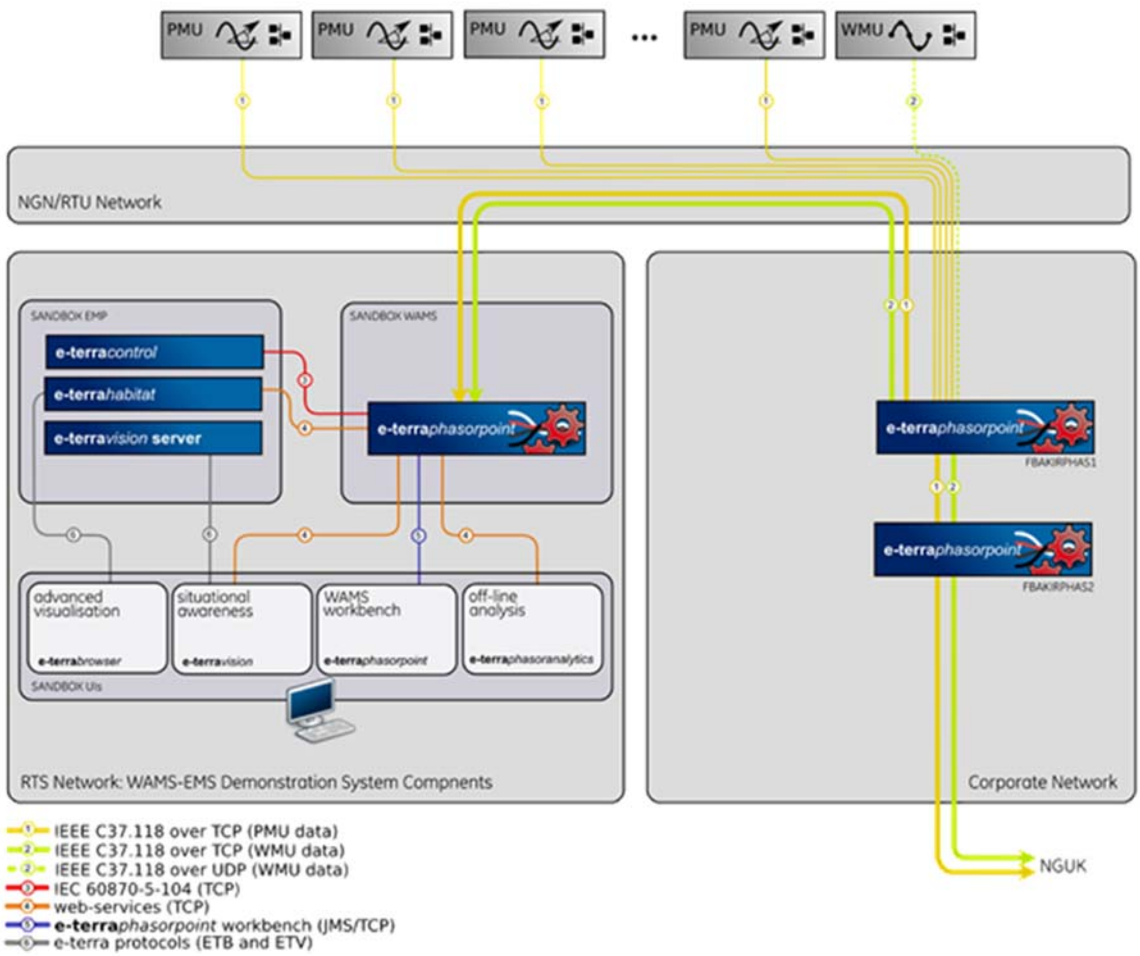


Figure 5. Key WAMS-EMS integration components and the proposed architecture connections

Sandbox training

A primary intention of the WAMS-EMS Demonstration System is to enable familiarisation of operators and other key control room personnel with the use of e-terraphasorpoint in an integrated WAMS-EMS environment.

A number of initial training sessions shall therefore be held, to introduce the core principles, functionality and hands-on usage of the integrated WAMS-EMS software. Repeated sessions shall be arranged to allow for availability of personnel. The following topics shall be covered:

Table 2. Training topics to be held at the Sandbox demonstration facility

Training Topic	Format	Duration	No. sessions
Introduction to WAMS concepts	Classroom	⅓ day	3
Introduction to use of e-terraphasorpoint	Classroom with practical examples	⅓ day	3
Use of WAMS in improving real-time Situational Awareness	Classroom with practical examples	⅓ day	3
WAMS data integration using Grid Stability Assessment (GSA) tools, alarm integration and State Estimation	Classroom and practical examples	½ day	3
Historical phasor analytics capabilities using e-terraphasoranalytics	Classroom and practical examples	½ day	2
Training for IEC 60870-5-104 configuration for State Estimation and integration	Hands-on	½ day	2
Typical software configuration and system administration tasks pertaining to Sandbox	Hands-on	1 day	1

2.6.2 PMU/WMU data visualisation tool for mobile platforms

The project is delivering a suite of user-orientated software applications to utilise the phasor data gathered in the project, but these tools are complex in nature and are designed as engineering solutions. There remains a need for high-level presentation and educational tools aimed at non-technical stakeholders, such as senior managers that are unfamiliar with the power system operation & analysis concepts involved and with operational tools such as the EMS or PhasorPoint. The ability to illustrate and interact with PMU/WMU data at a high-level to personnel outside of the control room and system monitoring domains has been identified as a valuable way of demonstrating the benefits of WAMS-related information clearly.

A workstream was subsequently identified to develop an independent framework to provide high level presentation of and open access to the PMU data, to complement the existing proprietary solution. This will allow access to the data using a web browser for local and remote access with the data stored separately from the existing solution in an open-standard format, and make this data more open and accessible to other users outside the existing PMU analysis environment.

Open Grid Systems is a Glasgow-based company that have developed mobile applications to present network data and could be developed to accommodate PMU data and alarms such as that gathered in VISOR. Figure 6 illustrates Open Grid System's interactive geographical management tool, *GridView.*

During the reporting period, a contract was placed with Open Grid Systems to provide a tool similar in essence to GridView, but with the ability to receive PMU/WMU measurement data and alarms, and creating a visualisation and interactive geographical platform in a similar manner.

The development of this tool has the following primary objectives:

- To provide a means of accessing, visualising and interacting information attained by VISOR across multiple platforms, i.e. mobile phones and tablets
- To bolster effort's to bring VISOR to the wider stakeholder community, in particular non-technical engineers without access to PhasorPoint

Figure 6. Illustration of GridView application for mobile platforms

Open Grid Systems have recently worked with our colleagues at SHE Transmission and in a number of areas that relate to this project with existing products and technology, including:

- Existing frameworks to support geographical visualisation of network model data, including:
    - Powerflow solution visualisation with animated line flows
    - Voltage magnitudes overlaid as *heat maps*

   - o Flow-based market simulation results with dynamic line colouring based on interactive simulation controls
- Mobile applications for field crews to provide online and offline access to network models and configurable overlays of real-time data including live incidents, crew locations and substation protection settings.
- Active research work in collaboration with Brunel University London and Lawrence Berkeley Labs looking at cloud-computing applications for micro-PMUs including line parameter estimation and automated deployment of devices.

The beta of the application is due in July 2016, ahead of the next stakeholder event, with a final version to be released later in 2016.

2.7 Oscillation Monitoring and Management

Monitoring of "Low Frequency" (LF) 0.1–4Hz oscillations, typically electromechanical (inter-area, plant and local) modes, using synchronized measurements from PMUs is already established. The reducing and variable inertia of the GB system, together with the recent closure of large synchronous generation units with a power system stabilizing role, the deployment of series compensation and the proliferation of Power Electronic systems, necessitate extended and enhanced monitoring of power system oscillations in GB. In particular, there is need for:

- New tools to aid in identifying the sources of oscillations – in both real time and study domains.
- Renewed focus on oscillations in the 0.002-0.1Hz governor or "Very Low Frequency" (VLF) range, driven by changing system inertia.
- New monitoring of the 4-46Hz range, termed "sub-synchronous oscillations" (SSO). This is motivated by the risk of interaction between new series compensation, power electronic controls, and generator shaft torsional modes.

VISOR is demonstrating new WAMS analyses, applications and infrastructure to meet these needs.

	Application	Frequency Range	Inputs	Outputs	Type of Mode
NEW	**Very Low Frequency (VLF)**	0.002-0.16	System Frequency	Mode Frequency Mode Amplitude (system–wide values)	Common Modes
NEW	**VLF Source Location**	0.002-0.16	Angle Power	Source Location	Common Modes
EXISTING	**Low Frequency (LF)**	0.1-4 (Legacy 0.04-4)	Frequency Power Angle difference	Mode Frequency Mode Amplitude Mode Damping	Local and inter-area modes
NEW	**LF Source Location**	0.1-4	Frequency (from Angle)	Source Location	Local and inter-area modes
NEW	**Sub-Synchronous Oscillations (SSO)**	4-46	Voltage waveform Current waveform (@ 200Hz)	Mode Frequency Mode Amplitude Mode Damping	Sub-Synchronous Oscillations (e.g., torsional, network LC modes)

Figure 7. Oscillatory Stability monitoring in PhasorPoint

The tools being demonstrated provide real-time wide-area monitoring of oscillations across the entire 0.002-46Hz range. The results are presented in real-time geographic displays for operator situational awareness, feed alarms to warn of emerging issues, and are stored for historical trend and event review. Source location analysis is also performed in real-time, presented to users on a geographical display and stored for historical review.

During the reporting period, the following two tools have recently been deployed, and have already provided valuable insight into grid behaviour.

2.7.1 LF (Low Frequency) Oscillation Detection and Source Location Enhancement & VLF (Very-Low Frequency) Oscillation Detection and Source Location

GE successfully completed the development of the LF and VLF oscillation detection and source location applications which were presented on 30 March 2016. These applications have now been deployed to the PhasorPoint servers at NGET and SHE, and will be deployed at SPEN shortly.

Although poorly damped oscillations are rare in the GB network, they do occur. The VISOR WAMS is enabling the establishment of a reference baseline of system behaviour. From this, suitable monitoring thresholds can be configured, and comparison with newly witnessed oscillations can be drawn. This baseline will continue to grow as time goes on, and the increased proliferation of PMU and WMU devices will provide more detailed records of such events that will increase accuracy and reliability of analytical tools.

An oscillation mode at 0.54Hz has been observed with 55MW swings in one (of four) lines in the Scotland-England corridor. In addition to this 0.5Hz mode, there has been a mode at 0.7-0.8Hz observed with incidences of poor damping over several years. Although this mode has not been known to grow in amplitude, it is seen over a wide area from Scotland to the south of England. Prior to the VISOR project, there was little information to identify the location of the main contributors to such oscillations. Application of the new VISOR source location analysis to incidences of poor damping observed during this project have consistently indicated that the closest monitoring point to the source of oscillation was in the generation-rich Humber estuary region (Figure 8). Restoration of PMU visibility to two temporarily unmonitored regions – South-West England and Northern Scotland – will provide further detail of the contributions.

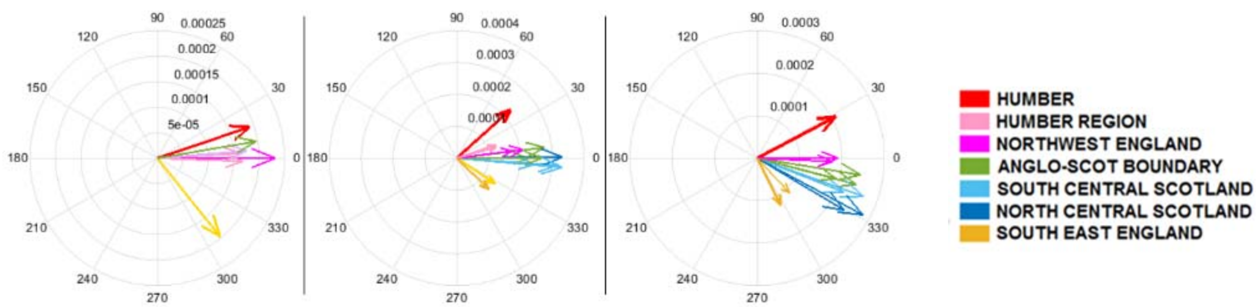


Figure 8. Mode shape of 0.79Hz oscillation across 3 separate events, showing Humber leading the group, indicating a significant source near the monitored point

2.7.2 The B6 Boundary Application

The B6 Boundary application was demonstrated in the previous period and discussed in the December Project Progress report, submitted in December 2015. As highlighted within the report, the application does not allow for easy simulation or interrogation which restricts the ability to demonstrate different simulation cases and thus the tangible benefits using the application.

In order to support business case development and demonstrate the benefits that may be realised by using this application in the control room, National Grid SO have initiated a study examining the potential benefits based on measurement data gathered during VISOR.

2.7.3 Line Parameter Estimation

Initial studies into the Line Parameter Estimation were conducted in 2015 but concluded that poor data quality hindered the ability of the software to accurately perform this analysis. Efforts have since been made to address these issues, and further assessment will be made later in the project.

2.8 Research at the University of Manchester

Over this reporting period The University of Manchester has continued research into sub-synchronous resonance (SSR), with a focus on determining how proximal modes must be for interactions to occur and if a band of interaction exists around a mode, i.e. answering the question “how close is too close?”. Furthermore, work has continued from the previous reporting period into the impact of load models on SSR studies and how loads interact with SSR, with a view to possibly developing supplementary control loops that will allow motor loads to contribute to the damping of SSR.

This period has also seen the preparations for delivery of the dynamic model validation work package that is the University’s responsibility. A plan has been developed for the time that UoM researchers will spend on site at National Grid to work with the full GB model. This work will be performed early in Q3 2016 with the objective of studying the use of the VISOR WAMS for validating the GB power system model in terms of the frequency response after large disturbances and the small signal behaviour of the model.

Furthermore, during this reporting period the University held an internal workshop for the project partners, in which the research performed by the University was presented. The workshop provided the opportunity for detailed discussion of this work and the opportunities for further development, both as part of VISOR and after the close down of the project. It is hoped that this workshop will serve as the basis for the presentation of relevant aspects of the UoM’s work within the partner businesses in the future.

The most significant research outputs during this reporting period are:

- The final revision and acceptance of the paper entitled “Impact of Load Dynamics on Torsional Interactions” for the prestigious Power System Computation Conference (PSCC);
- The first revision of the paper entitled “A Screening Rule Based Iterative Numerical Method for Observability Analysis” that has been submitted to the IEEE Transactions on Power Systems;

- The submission of the paper entitled "Investigation of the existence of a Sub-synchronous Resonance Interaction Band" to the IEEE Transactions on Power Systems.

2.9 Knowledge Sharing and Stakeholder Engagement

The VISOR team is committed to knowledge sharing and effective stakeholder engagement to ensure that VISOR can adopt the latest technology advancements, share the lessons learned by/with other stakeholders, facilitate new entry to the market and disseminate the key learning captured along the VISOR delivery.

As the project progresses through the operational phase it is essential that generated learning is communicated throughout the businesses, and the wider audience, to guarantee the project is on the right path for further progression into the businesses.

During the reporting period project VISOR has focused on both external and internal knowledge dissemination through the following key activities.

Hosting the following dedicated events:

- Key internal stakeholder event in the SPEN Operational Control Centre, Kirkintilloch, 4th February 2016.
- Knowledge sharing seminars with international WAMS expert, Vahid Madani, Pacific Gas & Electric's Synchrophasor Project Lead, at Glasgow and Wokingham, 1st-3rd February 2016.
- PhasorPoint Application Demonstration Workshop (VLF & LF), Edinburgh, 30th March 2016
- First round of Roadmap Interviews with different function areas of the TO and SO business, 18th – 22nd April 2016.
- Academic Workshop and Research Presentations, Manchester, 2nd June 2016.

Furthermore, to increase engagement and involvement with external stakeholders, in particular to share international experience of WAMS deployment, VISOR has been presented at the following events:

- NASPI Working Group meeting, Atlanta, 24th-26th March 2016
- New York ISO teleconference presentation
- Central Maine Power teleconference presentation
- Protection & Control World (PAC World) 2016 conference (13-17th June, Ljubljana, Slovenia): paper entitled "VISOR Project: Initial learning from Enhanced Real Time Monitoring and Visualisation of System Dynamics in Great Britain"

The following events are forecast during the forthcoming period:

- PSCC Conference, Genoa, 20th-24th June 2016 – two papers are being presented:
    - Impact of Load Dynamics on Torsional Interactions

  - Addressing Emerging Network Management Needs with Enhanced WAMS in the GB VISOR Project
- IEEE General Meeting, Boston 17th-21st July 2016
- CIGRE Conferences, Paris, 21st-26th August 2016
  - A joint paper with the National Grid "Smart Frequency Control" NIC project, entitled "Advances in Wide Area Monitoring and Control to address Emerging Requirements related to Inertia, Stability and Power Transfer in the GB Power System"
  - A joint presentation in the GE suite on the VISOR and Smart Frequency Control projects.

In addition to the above activities enhancements have been made to the VISOR website2, with the inclusion of informative and educational multimedia and improved document sharing. Over the forthcoming periods, the website will become the focal point of stakeholder engagement and will include event tracking facilities along with the ability to access a wealth of VISOR and WAMS learning.

2.9.1 Feedback from Stakeholder Events

We have conducted a number of internal stakeholder events to communicate the learning and experience from VISOR and international projects to key business functions; ranging from staff within the Operation Control engineers at Kirkintilloch and Wokingham, to Post-Operation Analysis engineers at Cambuslang, and System Planning and Protection engineers at Blantyre and Warwick.

Throughout these events, the goal has been to enhance understanding of the project's aims and objectives but also to, crucially, ensure these objectives remain aligned with the needs of the different functions within the businesses. The PDT recognises the importance that specific concerns or uncertainties are addressed so that the businesses understand the requirements and the benefits, in order to be best equipped to embrace this technology.

The feedback from the internal stakeholder events has been positive, with each party showing interest in understanding just what the tangible benefits of the technology are, in terms of their roles and responsibilities. The Innovation Day at SPEN's Control Centre allowed the operational control and planning engineers to witness the various applications enabled by WAMS technology.

[2] Project website: www.spenergynetworks.co.uk/visor

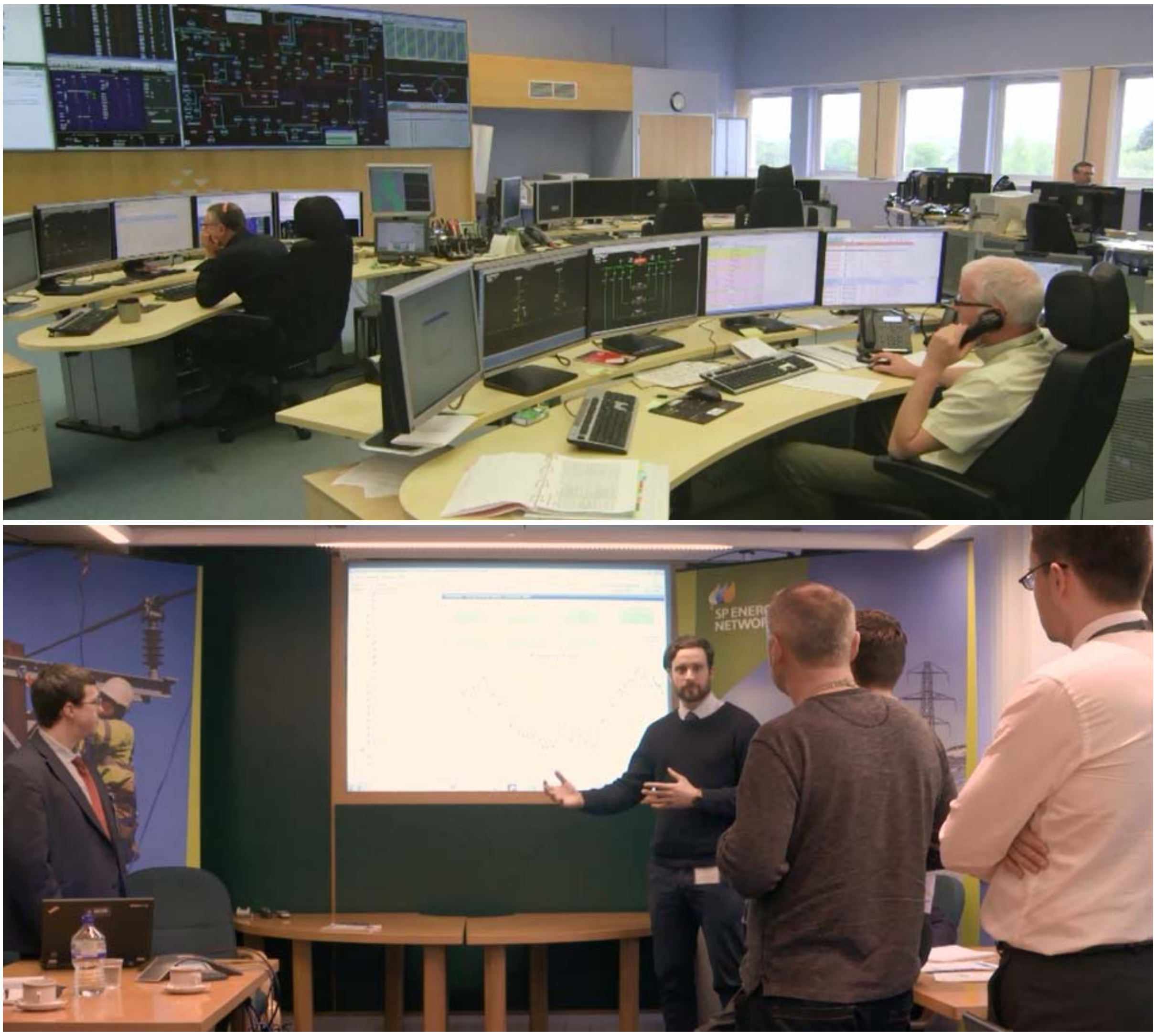


Figure 9. VISOR Innovation Day at the SPEN Operational Control Centre, Kirkintilloch

One particular quote from a SPT Senior Control Engineer, Joe Hunter, is noteworthy and illustrates the importance role WAMS technology has present and future electricity supply industry:

> ***“The changes in generation on the transmission network, particularly in Scotland, means that the intuition of system behaviour our experienced control engineers have developed over the past 20 years no longer applies. Sophisticated software applications are now becoming crucial to understand and manage the network within the parameters set.”***

VISOR was also presented at the North American Synchrophasor Initiative (NASPI) International Synchrophasor Symposium on the 22nd March 2016. The NASPI community is working to advance the deployment and use of networked phasor measurement devices, phasor data-sharing, applications development and use, and research and analysis, and the PDT welcomed feedback expressing similar experience and challenges of the technology.

The accelerated adoption of WAMS technology in North America is largely a result of the Northeast Blackout of 2003 affecting 55 million people; following which the U.S. Department of Energy (DOE) and the North American Electric Reliability Corporation (NERC), along with involved electric utility companies and other organizations, made available substantial funds and formed the North American Synchrophasor Initiative (NASPI).

The SSO monitoring aspect of the VISOR project gained particular attention from the NASPI community which subsequently led to two teleconference presentations to the two Independent System Operators (ISO), New York ISO and Maine Power ISO.

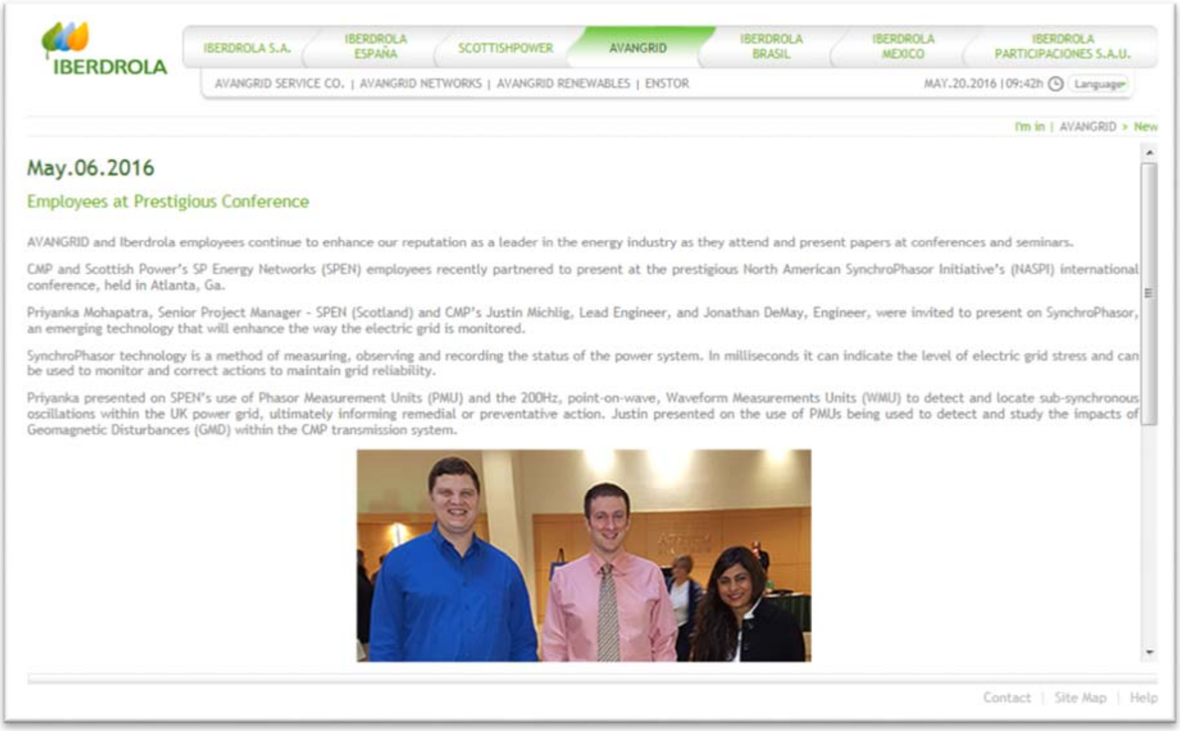


Figure 10. Iberdrola Global internal press release of VISOR at Prestigious Synchrophasor conference, NASPI

2.10 Outlook to the Next Reporting Period

Looking ahead to the next six months, the PDT will focus efforts in ensuring the project is best positioned for transition into the businesses with particular focus on internal engagement with senior management and through the following activities:

1. Dedicated VISOR External Stakeholder Event in London
2. Internal stakeholder engagement and training events at the Sandbox facility
3. Workshop and Presentation of WAMS use-cases, benefits, investment options and implementation strategies conclusions from the VISOR Roadmap.
4. External stakeholder engagement, in particular the dedicated VISOR event and the LCNI conference.
5. IEEE General Meeting, 17th-21st July 2016, Boston, USA.
6. Cigre Conference, 21st-28th August 2016, Paris, France
7. LCNI 2016, 11th-13th October 2016, Manchester, UK.

In addition to these activities, there are a number of deliverables expected for completion within the forthcoming reporting period including a number of key reports detailing the findings from widespread system monitoring, as listed below and in accordance to with the VISOR project direction.

SDRC 9.3.1

- Report on accuracy of simulation models for small-signal and large-signal against naturally occurring events (WP 2.2-2.3, Dec 2016)

SDRC 9.4.1

- Report on quantification of uncertainty in stability calculations (WP 3.1, Dec 2016)
- Report on findings from benefits of hybrid state estimator (WP 3.2, Dec 2016)
- Report on long-term monitoring of area angle measurements (WP 3.4, Dec 2016)

SDRC 9.6.1

- Academic partner delivery of knowledge capture and publications (WP 5.2, Dec 2016 - Mar 2017)
- Presentations and show-casing at the annual innovation conferences (WP 5.4, Dec 2014, Dec 2015, Dec 2016 and June 2017 for Close-down report dissemination)

3 Consistency with full submission

At nearly 24 months into the project delivery, VISOR remains been consistent with the original full submission with regards to resources allocation, project management and project programme.

These consistencies demonstrate the level of detail of the original submission, robust project management currently in place and set a solid foundation for the future delivery.

4 Risk Management [Confidential]

The complicated technical nature and multiple interfaces between TO/SO, project partners and suppliers present the most significant challenges. Monthly PDT meetings enable the VISOR Project Delivery Team (PDT) to take a proactive approach of regularly reviewing the risk register, allocating clear ownership of each risk and putting in place appropriate mitigation measures. Furthermore, the regular PDT meetings allow new risks to be highlighted and managed in a timely and efficient manner.

For project delivery, the involvement and corresponding interfaces between each project partner and suppliers are critical to the success of the project. Dedicated project managers have been appointed within each organisation to coordinate the project delivery resources and identify risks. Identified risks should take into account the interfaces and governance within each organisation. The following section details the key risks identified and addressed in the reporting period.

4.1 Project Management Risks

4.1.1 Key Project Management Risk

The most significant project management risk during the reporting period was the coordination between personnel at BT, NGET and SPT in order to commission MPLS link correctly.

A summary of the project management risks affecting the project during the reporting period, and beyond, are tabulated in Table 3.

Table 3. Project Management risks to the project during the reporting period

Risk Description	Mitigation Action
Integration of innovation into business as usual activities: Uncertainty surrounding the true benefits of phasor information will hinder the roll-out into BaU.	• **New initiative to establish a Sandbox facility for pre-deployment testing and training.** • Drawing upon international experience of WAMS deployment • Internal knowledge dissemination throughout vital to ensure benefits of project are widely known, including seminars with international experts
Establishing a successful continuation plan The ultimate success of the project will be determined by the onward progression into BaU. In order to best position the technology, the VISOR project must address the following risks: • Uncertainty of business case for both TO & SO • Lack of experience of confidence in the WAMS technology and applications • Increased data must not impede other BaU practices	• **Benefits of the technology to support a business case must be documented and presented to senior management, with support from key stakeholders/end users.** • Ensure the necessary internal stakeholders are engaged and involved during the timeframe of the project • Learn from international experience • Produce continuation plan – roadmap addressing Processes, Infrastructure and personnel

• Dissipation of the project team and resultant loss of their expertise • On-going support of the VISOR infrastructure	
Successful commissioning of MPLS link between SPEN and NGET: Coordination of multiple companies, with different departments involved for different aspects. Timely delivery required to avoid knock-on delays. • Lead time and complexity in provisioning communication links with multiple vendors • Lack of coordination between IT departments to establish communication infrastructure • Coordination of service providers in commissioning network links due to contractual constraints causing delays of installation of the MPLS between data hub and SPT Datacenter	• Proactive engagement with Verizon to monitor progress of BT installation • Regular review and impact assessment at monthly PDT meetings, including financial implications • Coordination between project partners to ensure IT departments are engaged ahead of schedule to minimise possibility of future delays • Execution of contingency plan to overcome delays
GB System Model Access: Offsite access to National Grid system models and system data was identified early in the project as a possible risk for the dynamic model validation work package and SDRC.	• **Mitigation actions were put in place and these allowed this work to proceed with limited delay when it proved impossible to provide UoM with offsite access.**
Ongoing prioritisation for system access to install monitors and modify existing PMUs: Installation and modification of hardware in transmission substations typically require an outage, and therefore need significant advanced planning to ensure delays are kept to a minimum.	• Sites works are arranged to piggy-back on ongoing schemes to manage system access restrictions.

4.2 Technical Risks

The following technical risks were encountered during commissioning and system analysis for project VISOR from January 2016 to June 2016.

4.2.1 Key Technical and Roll-Out Risks

The most significant technical risk uncovered within this reporting period are around the data transfer via the MPLS link. Once fully operational, the comparison between IP-Sec and MPLS will represent valuable learning to inform the development of the technology Roadmap.

Another key risk is the timely commissioning of the VISOR Sandbox test facility. Previous experience may suggest that delays in establishing new infrastructure with the secure environment is likely. Aside from the fact that the commissioning cannot begin before a previous programme has concluded which in itself introduces a delay risk, the PDT remain hopeful that by drawing upon previous experience the coordinated design and implementation of this task will be managed closely to help avoid unnecessary delay.

A summary of the other technical risks affecting the project during the reporting period, and beyond, are tabulated in Table 4.

Table 4. Technical risks to the project during the reporting period

Risk Description	Mitigation Action
Configuration of data transfer and firewall - Cyber Security (Critical National Infrastructure) The interaction between Monitoring Devices (PMUs & WMUs) and VISOR TO Datacentres (PDCs), and those between the VISOR TO Datacentres and VISOR SO Data Hub (both PDCs), presents security risks. The different companies have different IT policies and security arrangements to protect from external threats. The key challenge is in ensuring that security of national infrastructure is not adversely affected, with the risk being that a mutually acceptable solution will not be agreed by all parties.	• Coordination between IT departments required to ensure necessary security features (firewalls, VPNs, ports) are configured appropriately • Foresight given to continuation plans and possible means of integration into secure RTS/CNI n, post project
Configuration of MPLS link between SPT and NGET The risk that the link does not perform as desired within the timescales of the project, hindering the ability to conduct meaningful comparative assessments with the IP-Sec link to inform Roadmap	• Determining the optimum roadmap will have to wait to learn the findings from this assessment, however preliminary comparisons can be made with international experience.
Configuration of test facility The new facility is intended to bridge the gap between innovation and BaU for all project partners by providing a live demonstration of the integration of WAMS in EMS/DMS applications. The risk is the timely delivery of this facility in order to successfully demonstrate and undertake training within the environment.	• Coordination between IT and GE for specification and design of suitable facility. • Preparation of training and demo schedule to ensure maximum value obtained from training days. • Multiple training events to allow for calendar conflicts.
Data quality and availability affecting accuracy and development of applications Risk initially identified in previous PPR whereby data availability and quality posed risk to accuracy and applicability of oscillation detection and location.	• The availability of higher quality data from new WMUs and a subset of the existing PMUs (if communications issues are resolved) will mitigate the effects of this.

Extensive analysis identifies causes due to a range of factors, such as data gaps, GPS loss, and frequency quantisation. Mitigating actions taken / underway.	• Firmware upgrades to network and substation equipment which, on the basis of upgrades completed so far, appear to be significantly reducing data loss.
Server performance with increased data volumes Data archiving requirements exceeding storage capability of servers – addition of new PMUs beyond original VISOR scope adds value but increases data throughput and storage requirements. Performance impact of new applications (e.g. VLF, LF Source Location) on server load may be heavier than anticipated.	• The status and performance of the servers need to be monitored on a continual basis as more data is gathered from the network. • Upgrade options have been identified and are being implemented.
Sufficient confidence required for WAMS roll-out Culture and technological change will be met with apprehension and questioning. Technical difficulties identified within the trial project must be scrutinised and addressed to build confidence: • PhasorPoint server at SPEN was periodically crashing, believed to be influenced by poor data quality • SPEN WMU monitoring performance (90degree phase difference)	• Investigatory action to determine the cause and rectify, if required • Very specific nature and frequency of communications / data gaps identified as precipitating factor in crashes. Software patches and communications improvements have mitigated these, performance now greatly improved. • SPEN Server disk specification not optimal (unplanned adjustments made during procurement). Performance was evaluated, upgrade options have been identified and are being implemented. • Issues reported and scrutinised to instil confidence in WAMS technology and benefits. This contributes to learning and experience, to avoid issue during roll-out. • Trial of innovative technology aimed to demonstrate benefits and development of solid business case
Sufficient outage window for site access Installation of new WMU monitors to examine SSO behaviour and the WAMS infrastructure to communicate this data between TO and SO. The associated risks are • Individual WMU delays reduce granularity of SSO monitoring. Multiple delays restrict degree of learning	• Early engagement with planning and procurement teams. • Proactive programme management to retain coordination between suppliers/providers and site access • WMU orders to be combined and placed simultaneously for efficiency

5 Successful Delivery Reward Criteria (SDRC)

The Successful Delivery Reward Criteria set out in the Project Direction links with the Project Milestones and the identified targets directly. This SDRC can be used to check the progress of the project delivery and position the progress against the original proposal. Table 5 lists all the required evidences in line with VISOR project direction for reporting period June'15 – Dec'15.

Table 5. Achieved SDRC in reporting period

Successful Delivery Reward criterion	Evidence
9.1. Successful delivery of Sub-Synchronous Oscillation (SSO) monitoring prior to start of Series Compensation commissioning. **It is important that the project delivers an SSO monitoring capability in time to capture a baseline of the SSO frequency range performance before the series compensation is commissioned. The changes in behaviour can then be assessed against known historic behaviour. The components that should be delivered for success in this domain are:** • **Validation of SSO substation equipment** • **Installation, commissioning of SSO substation equipment & communication to central location** • **Integration to visualisation of SSO geographically**	9.1.1 • SSO Device qualification report (WP 4C, Dec 2014) • Visualisation of multiple SSO information sources at data centre (WP 1A, prior to the commissioning of series compensation reinforcement) • **Baseline and comparator report for SSO behaviour (WP 1, March 2015, March 2016, March 2017)**
9.2 Enhanced stability tools delivered, including Oscillation Source Location and Disturbance Impact **The applications to analyse and present stability information to real-time and analysis users is a key part of the project. The applications should be delivered and the necessary enhancements made to fulfil this criterion. Also, the test cases to prove and demonstrate the applications to end users are important for knowledge dissemination. The delivery includes:** • **Oscillation tools delivered to display wide area oscillations, including oscillation frequency, damping and mode shape** • **Source location tools for identifying contributions to oscillations** • **Disturbance detection, location, sequence and impact measures in application to manage high impact / low probability events** • **Review of the implications for future roll-out of PMUs for full GB-wide use of the applications**	9.2.1 • **Applications delivered and configured to include (WP 1.2, 2.3, March 2016)** o **Geographic oscillation alert presentation** o **Oscillation source location presentation for analysis & real-time** o Disturbance detection, location identification and impact measures • Report on PMU roll-out requirements for the applications (WP 4B, March 2017) • Simulation cases for presentation & training (WP 5.2, March 2017)

9.6 Successful dissemination of knowledge generated from VISOR project. **Knowledge dissemination within the transmission network owner is a key component to transfer experience for the pre-trial training and post–trial knowledge exchange. The key objectives of this work package are to successfully achieve the following:** • **Internal knowledge dissemination** • **External knowledge dissemination** • **Influencing and updating policies and standards** • **Public Engagement**	9.6.1 • **Establish on-line portal and keep up to date throughout project (WP 5.2, Sep 2014)** • **Timely delivery of project progress reports (WP 5.4, Sep 2014, Mar 2015, Sep 2015; Mar 2016, Sep 2016, Mar 2017)** • Academic partner delivery of knowledge capture and publications (WP 5.2, Dec 2016 - Mar 2017) • Presentations and show-casing at the annual innovation conferences (WP 5.4, Dec 2014, Dec 2015, Dec 2016 and June 2017 for Close-down report dissemination)

6 Learning Outcomes

Following the Authority's formal approval in December 2013, VISOR has made good progress regarding project partner collaboration agreement, project management and governance establishment, procurement and knowledge sharing. There are challenges and risks (as detailed in the section above and the Risk Register in Appendix 2) along the development, and lessons are derived from every aspect.

Lessons Learnt (+/-)	Lesson Learnt	Recommended Action
Positive	The presence of a contingency plan and coordination between PDT to overcoming uncontrollable delays.	By executing the contingency plan, the project milestones, and other dependant work streams, are not adversely affected.
Positive	Ensuring IT Security personnel are engaged with changes / developments in architecture design, particularly in pilot projects which can follow 'unconventional' routes into the business.	Ensure the successes of the new technology are controlled in such a way that 'new users' do not breach IT practices.
Positive	Importance of internal and external Stakeholder engagement. The stakeholder events enable the project team to engage with external expertise with similar experience that may represents great value for internal stakeholders.	VISOR will continue to focus on stakeholder engagement as the project progresses and ensure key stakeholder needs are understood and satisfied.
Positive	International experience of similar challenges, benefits, and deployment strategy of WAMS can be drawn from discussions and demonstrations of international utilities and advisory bodies.	Ongoing engagement with external parties, through conferences and dedicated meetings, to ensure learning acquired from others, where possible.
Negative	Early, direct engagement with business IT experts important for assuring technical requirements are understood on both sides that deployment schedules are realistic. This should be done at the tendering stage.	Business IT experts should be engaged and directly involved early in project delivery and specification stage to avoid potential risks and delays.
Negative	Need for greater emphasis on IT Infrastructure on System monitoring projects	Early engagement and direct involvementfrom all IT Partners from all involved parties to arrive at realistic estimates for the project

6.1 Technical Learning

The key learning generated to date is summarised below

The need for careful architecture design:

- Plans need to be comprehensive and clear from the outset (though this can be difficult on innovation projects). Information should include data flow details including direction, ports and protocols; and should cover both data streams and the support interfaces required – e.g. for remote configuration, debugging, and software / firmware upgrade. Access to control room and substation networks in particular is strictly controlled, for obvious reasons.

The need for flexibility and redundant approaches on inter-TO communications links:

- Original plans for a dedicated MPLS link between TOs – the technical and logistical option – were delayed by external contractors for 6 months. Escalation options were limited due to the multi-layered contractual relationships in place. The use of an IPsec link – initially rejected in favour of MPLS – was adopted as a short-term stopgap.

Export of large quantities of data for analysis – such as undertaken for model validation work and data reviews under VISOR – needs careful planning:

- The set-up of an external link for real-time or part-time streaming to a third party may turn out to be more efficient and straightforward than the regular connection of an external hard drive to a server located in a secure server farm. Similar consideration needs to be given to any backup philosophy.

6.1.1 Pilot: Corporate vs Critical Network

At the beginning of this project the decision was made to establish the VISOR system outside the project partners Critical Network Infrastructure and within the Corporate Networks. This decision was made for a number of reasons, including

- It is an innovation project with an as yet unproven applicability with unknown requirements and unquantified benefits.
- By virtue of being an innovation project it was not considered “Business Critical”.
- Company readiness for the technology was low and it may not have been possible to reach an agreement between SPT, SSE, and NGET within a sufficient timescale to install within their respective Critical Networks.

Situating the VISOR WAMS within the Corporate Network was the easier and less time-exhaustive approach and, as stated above, it may not have been possible to otherwise establish the cross-TO system within the strict timescales of the project.

As the original architecture did not have to adhere to the same levels of Cyber Security required for the Critical Network, a key challenge has stemmed from the successes of the technology subsequently being used by other functions of the business as part of business-as-usual - raising complexity and Cyber Security concerns.

The key lesson here is to consider such an eventuality wherein the scope for the technology may broaden or deviate based on the successes of the project, which must either be controlled or decoupled from the core project. Equally, serious consideration should be given at the design and planning stage to the potential for broadening of scope – such opportunities should not create delays or dependencies for the project, but consideration at an early stage will potentially lead to additional benefits being realised with minimal disruption and effort.

6.1.2 The importance and necessity of a Roadmap

The transition beyond a pilot project into the business requires strong evidence and business cases for the deployment of the technology. The full benefit of some applications, for instance the B6 boundary monitoring, may not be realised without changes to data-sharing agreements, for example, increased network visibility beyond the license area boundaries improve accuracy and robustness of network modelling and contingency analysis.

Equally, for applications such as oscillation source location and disturbance management to deliver most benefit to TOs, a high-level GB-wide view is required – this allows detected oscillations and disturbances to be placed in their proper context. With sparse visibility of voltage phasors (not commercially sensitive) across GB, TOs can see whether they are on the edge of an oscillation / disturbance or close to its centre, and can tell whether they are an active or passive participant. This information aids preparedness for possible further cascading events or growing oscillations, and supports analysts in investigating issues observed on their network that might be driven by behaviour elsewhere.

It is the responsibility of the PDT to develop these business cases to support the technology that may ultimately determine and support the required investment and the resultant benefits. Defining the tangible benefits of such a technology is a complex task, with many variable and uncertainties involved.

Such benefits include a number of potential approaches to release network capacity. Some approaches are relatively “low-hanging fruit” such as improved confidence in models and operating conditions – covered under VISOR. Other approaches will require real time contingency analysis and control, for which the System Operator may require other dependant infrastructure upgrades. These also require increased readiness and confidence from the industry to adopt such technology – the learning and demonstrations in VISOR are the critical first step in this.

Furthermore, benefits concerning reduced risk of catastrophe or damage to assets are difficult to justify without similar examples of catastrophes or near-misses whereby the technology would have avoided or reduced the impact. Although such events have and do occur in power systems worldwide, understandably these are not widely publicised and technical and financial details are scarce. VISOR is serving however to form and strengthen links with other utilities, which among other things will foster the sharing of such experience.

Building the WAMS Roadmap for the GB is complicated task, involving independent TOs and SO, and perhaps the key learning here is that this particular task should have a dedicated work package assigned.

6.1.3 TCP and UDP

Both TCP and UDP are used in WAMS across the world:

- TCP is connection-oriented protocol featuring reliable delivery (missed packets are detected and re-sent), albeit with an associated cost in larger packet size. In addition, as a connection-oriented protocol, traffic is always initiated by one party. In the typical WAMS scenario, the receiver (e.g. a PDC) will initiate the connection, requesting that the PMU start sending data. This has advantages for cybersecurity – only allowing traffic into the control room network that has been requested by a server within it.
- The alternative, UDP, is by comparison a connectionless “fire and forget” protocol with no guarantee of delivery. Furthermore, because there is no concept of a connection or an initiating party, firewalls must allow traffic to flow freely in both directions between the PMU and receiver. This can be a major problem for cybersecurity, particularly for strictly controlled environments such as a utility control network. However, the reduced complexity of UDP generally leads to smaller packets, less network traffic (no acknowledgement or resend requests) and faster send/receive processing relative to TCP.

UDP PMU streams will often undergo intermediate aggregation to a single stream and conversion to TCP at one or more PDCs situated outside of the secure operations network – for the cybersecurity reasons highlighted, as well as for bandwidth efficiency and buffering of data. This aggregation and conversion can be performed at a central, regional or substation level.

- Cybersecurity: as discussed above, the use of UDP to transmit PMU data to a WAMS server inside an operational environment (e.g. control room network) can present cybersecurity issues. This arrangement is not acceptable for operational deployment in GB – connections into the control room networks must use TCP.
- Traffic congestion: In VISOR, some isolated issues were encountered at certain PMU sites (resolved quickly), involving frequent TCP packet and connection drops. In such scenarios the resulting increase in traffic due to reconnect and packet resend requests might exacerbate any underlying congestion problem leading to increased packet loss and connection drops. In these (albeit rare) cases, data stream availability may be worse under TCP than if using UDP.

Experience to date suggests that for the roll-out of WAMS as an operational tool in GB, data must be received at the control centre via TCP. However in situations where network performance is a concern and/or PMU-based control is employed, UDP will likely form the first stage of the PMU data route. Aggregation for monitoring purposes and bandwidth reduction can then be carried out at a regional or central level, followed by conversion to TCP for reliable and security-compliant delivery into the control room environment.

6.1.4 Sub-synchronous Resonance – Load Interactions (SSR-LI)

An investigation of the impact of dynamic load modelling on EMT studies of SSR. Loads are classically either neglected or modelled as constant impedances for SSR studies. The objective of this work was to investigate this classical assumption by modelling different types of loads (aggregated at the bulk transmission level) to highlight their relative impact on the damping of torsional oscillations. The load types modelled are shown in Table 6.

Table 6. List of load types considered

Load Type	Description
Type 1	Loads neglected
Type 2	100% Const. Impedance
Type 3	50% DOL and 50% VFD based Motor loads
Type 4	100% DOL connected Motor load
Type 5	30% Const. Impedance 30% Const. Current 40% DOL connected Motor load
Type 6	50% Constant Impedance 50% DOL connected

Analysis shows that static load models give conservative results and the modelling of dynamic loads is of critical importance in order to capture system dynamics or transient behaviour for SSR studies, see Figure 11. Dynamic loads have been modelled as induction motors (DOL and drive based). Both open and closed loop VFD motor controls have been investigated. Case studies highlighting the impact of size and location of motor type loads in providing damping for torsional oscillations have been presented in detail. Results reveal that low inertia motors have the capability to provide better damping than high inertia motors because their speed oscillations closely follow Sub-synchronous frequency oscillations. However, the load location plays a particularly important role in determining the damping, as it affects the power flow through the series capacitor.

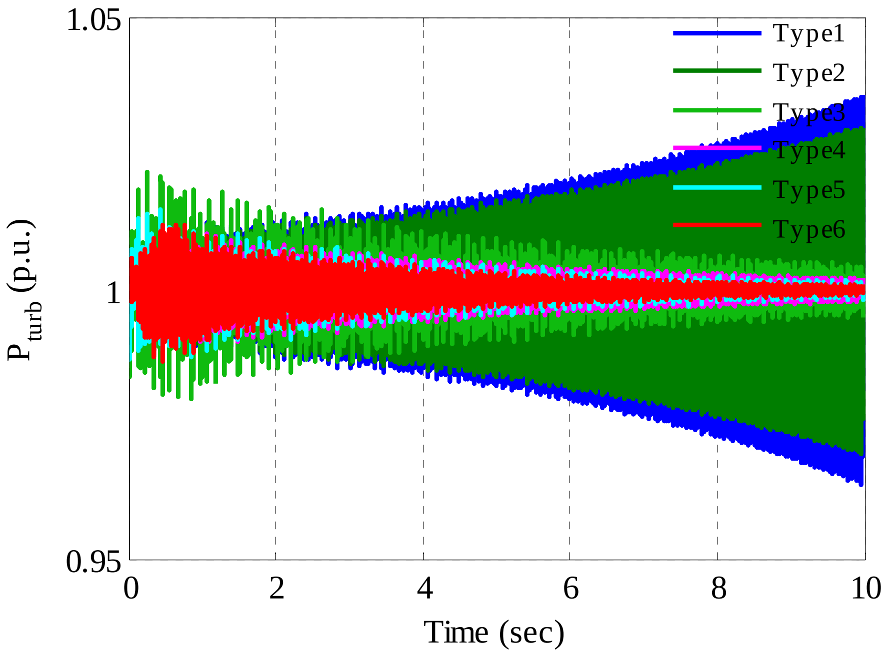


Figure 11. Damping comparison for different load model

The phenomenon of Sub-synchronous Resonance Load Interaction (SSR-LI) for conditions where the load centres are electrically close to the generation centres has been introduced and discussed for both DOL and VFD based dynamic motor loads.

It was found that torsional oscillations could propagate across passive front end VFD motor loads, see Figure 12, and the negative impact of Sub-synchronous components appearing at the motor terminals has been discussed in terms of motor operation.

Figure 12(a) presents speed oscillations at different points of the generator-turbine shaft, i.e. exciter (speede), high pressure turbine (speedh), intermediate pressure turbine (speedi), low pressure turbine stages A and B (speedla,speedlb), along with corresponding FFT results. Figure 12(b) presents the oscillation in the turbine output power (Pturb) and its corresponding FFT. Figure 12(c) presents the dc link capacitor voltage (VDC) of the VFD and its FFT, which indicates that the torsional oscillations can pass through the diode bridge to appear on the dc side and may then propagate to the motor side through the VSI. Figure 12(d) shows that this oscillation reflects on to the machine electrical torque (Te) which starts oscillating across the mechanical load torque (Tm) of the motor. It is interesting to see a 25 Hz frequency component appearing at the motor terminal in addition to the 5th and 7th harmonics that are characteristic of the 6-pulse inverter.

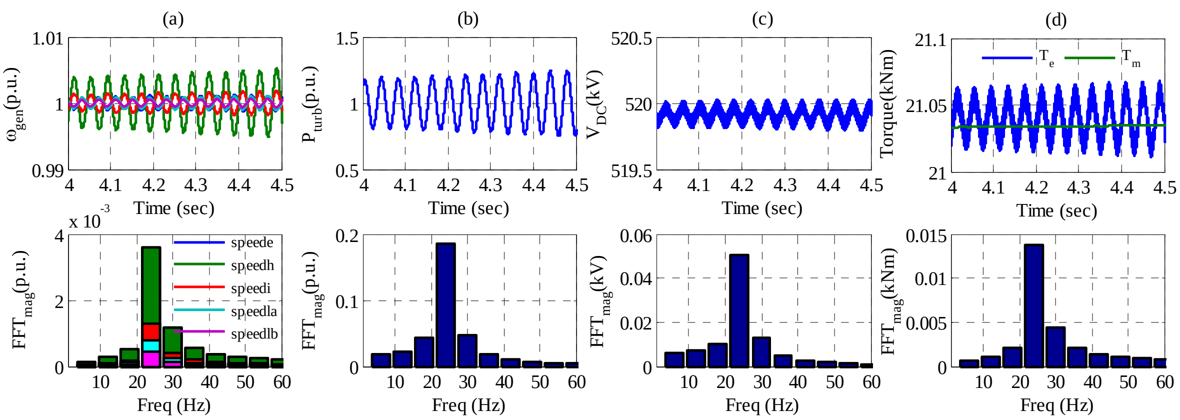


Figure 12. (a) Generator-turbine shaft speed, (b) Turbine output power, (c) VFD dc link capacitor voltage and (d) Motor torque

It was found that the location and size of motors had a significant impact on the damping they provide. An interesting example of this was that a high inertia motor would provide more damping when connected closer to the generator, whilst a low inertia motor would provide more damping when it was remote from the generator. Furthermore, a remote low inertia motor provided more damping than a high inertia motor that was close to the generator, see Figure 13. This can be explained by studying the phase relationship between the motor speed and machine frequency, in Figure 14.

These results have indicated that it may be worth pursuing research into the novel use of motor loads to provide damping of SSR.

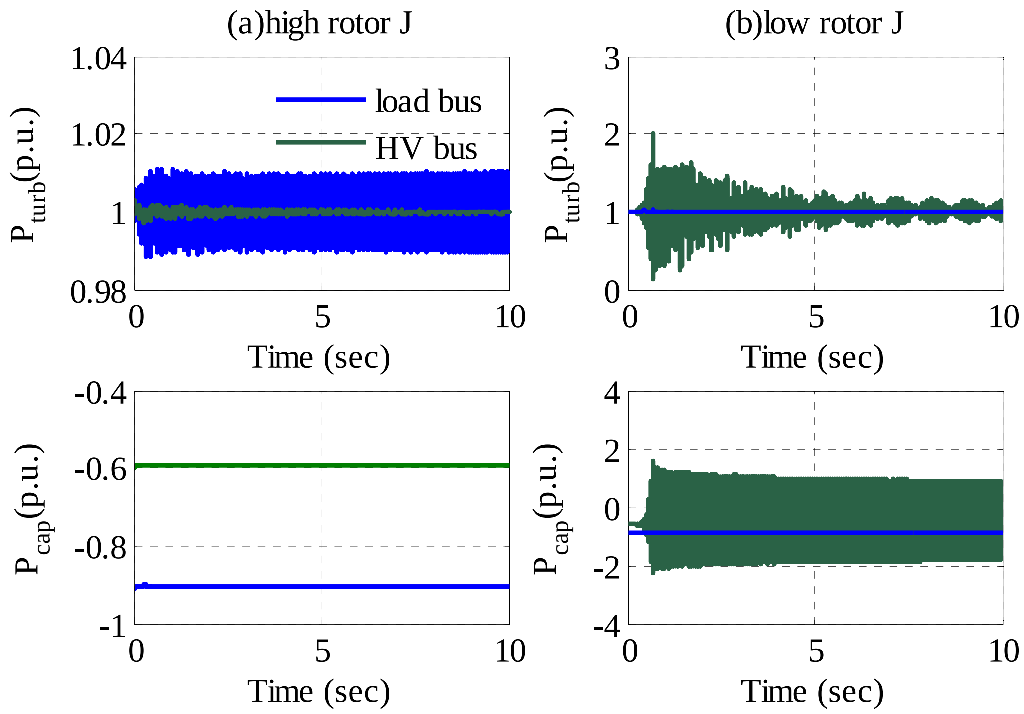


Figure 13. Impact of motor shaft inertia and motor location on SSR damping. For the high inertia motor Jagg= 39027 kgm2 and for low inertia it is 18212 kgm2

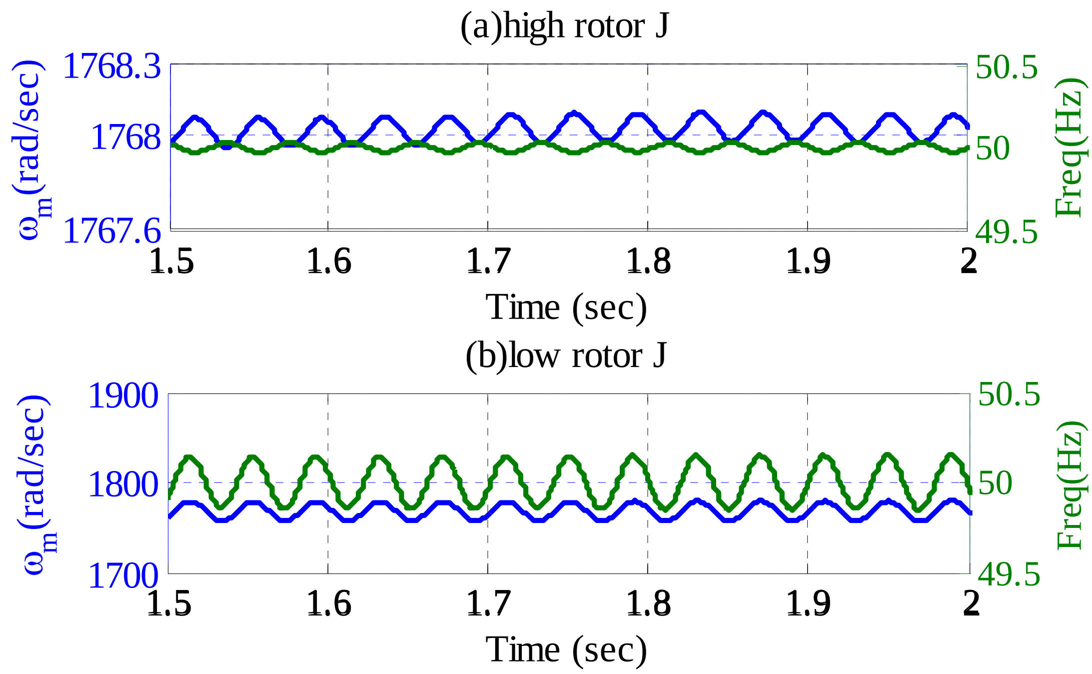


Figure 14. Phase relationship between motor speed and bus frequency when a high inertia (a) and low inertia (b) motor loads are connected at the load bus

6.1.5 Sub-synchronous Resonance – Interaction Bands

In the past six months a first of kind study of the concept of a Sub-synchronous Resonance Interaction Band (SRIB) has been completed. The SRIB is defined as the band of frequencies for which the given torsional mode will interact with the resonant electrical mode complement to produce SSR. It has used frequency scan results and exhaustive EMT simulations for the IEEE 1st Benchmark Model and calculation of undamping to study the relevance of the proximity of electrical resonant frequency complement and fixed mechanical torsional modes in terms of defining when resonance will occur, i.e. to answer the question: *how close is too close?.*

The analysis began with an assessment of the adequacy of the only existing research that is close to defining such a band (±3 Hz band). The results presented are summarised in Figure 15 and Figure 16 and have led to several significant conclusions about the nature and existence of the SRIB and through this enhances our understanding of the phenomena of SSR.

The most significant conclusions are:

1. The frequency of the torsional mode does not appear in its own SRIB, i.e. if the complement of the electrical resonant mode is equal to the torsional mode frequency there is no SSR.
2. The SRIB for a mode can be very close to one mode (e.g. within 0.5 Hz) and the interaction can still occur with a more distant mode (e.g. within 5 Hz).
3. The SRIB for each torsional mode is not of equal width and, as the torsional mode does not appear in the SRIB, it is not symmetrical about the torsional mode.
4. The SRIB appears with an offset from the torsional mode. This offset increases as the frequency of the mode is reduced, i.e. the SRIB is further way from the low frequency modes.
5. The SRIB does not coincide with the peak undamping of the mode.
6. The SRIB is the same, regardless of which signal is used to identify it (e.g. terminal voltage or turbine speed), despite the fact these signals include both electrical and mechanical properties. However, the participation of each signal in the different modes does vary significantly.

In the future, realising a generic definition of the SRIB that can be used to identify the true frequency ranges around the torsional modes of a generator, in which it may be vulnerable to SSR, could be of great value. For example, understanding these bands may allow the creation of online alarms that are precise and reliable. Furthermore, this enhanced understanding of SSR may help to realise the creation of enhanced, low cost control measures that could facilitate the further use of fixed series compensation.

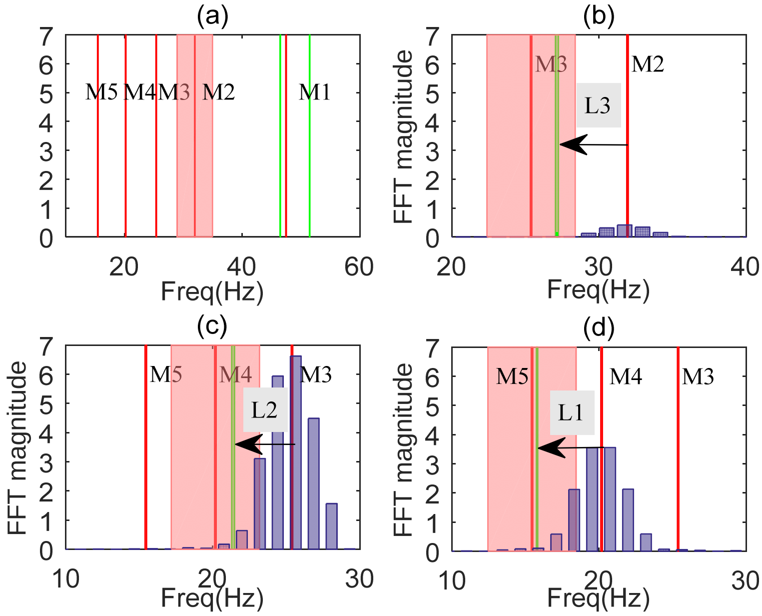


Figure 15. (a) Five mechanical modes, red lines, and ±3 Hz band, red shaded area, and RLC mode complements, green lines.. (b) FFT plot of turbine power output (Pt) for 42% compensation. (c) FFT plot of Pt for 58% compensation. (d) FFT plot of Pt for 76% compensation

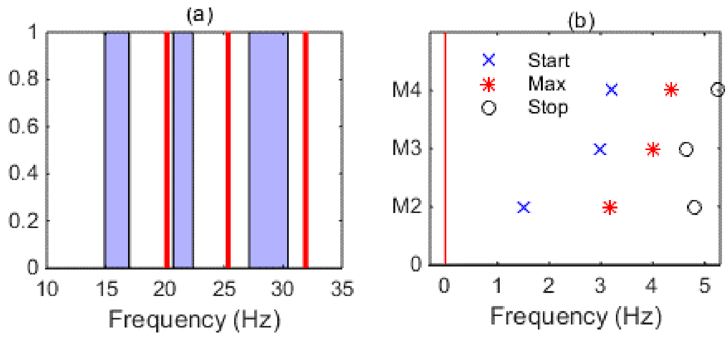


Figure 16. a) Resonance interaction band as determined from the study shown in blue around the fixed mechanical torsional modes in red (M2, M3 and M4). (b) Scatter plot illustrating the distance of electrical mode compliments from the fixed mode for the start, maximum and decay of SSR interactions

7 Business Case Update

We are not aware of any developments that have taken place since the issue of the Project Direction that affect the business case for the Project.

8 Bank Account

A dedicated bank account was made available by SPT to act as the Project Bank Account in to which NGET, as the GBSO, deposited the appropriate project funds through 12 monthly transfers in the Regulatory Year commencing 1 April 2014, such that the total amount transferred equals the net amount set out in the Funding Direction.

The table below documents the breakdown of the overall spend as of 14 June 2016. The accompanying VISOR bank statement is provided Appendix 1.

Table 7. VISOR cost breakdown, June 2016.

	Contractor	Direct Labour	Equipment	IT	Knowledge Dissemination	Travel	Grand Total
2014							
04/14		£11,330.00					£11,330.00
05/14		£11,330.00					£11,330.00
06/14		£11,330.00					£11,330.00
07/14		£11,330.00			£3,446.00		£14,776.00
08/14		£46,621.40		£12,563.62			£59,185.02
09/14	£66,693.00	£11,330.00					£78,023.00
10/14	£104,789.83	£86,537.04				(£4.04)	£191,322.83
11/14	£9,791.80	£13,180.40		£6,181.94			£29,154.14
12/14	£9,558.84	£3,846.20	£18,575.00	£3,164.62	£413.42	£6,269.86	£41,827.94
2015							
01/15	£83,711.00	£198,787.03			£555.00		£283,053.03
02/15		£43,398.40					£43,398.40
03/15	£19,697.00	£175,440.05				£3,033.66	£198,170.71
04/15		£42,848.16				£1,879.53	£44,727.69
05/15	£5,264.00	£41,618.63				£112.01	£46,994.64
06/15	£51,408.67	£71,427.12				£4,539.85	£127,375.64
07/15		£175,022.46		£311.30		£5,391.54	£180,725.30
08/15	£77,474.12	£28,840.00		£302.91			£106,617.03
09/15	£3,254.65	£147,844.48		£386.69			£151,485.82
10/15	£31,484.00	£28,840.00		£54.91	£6,549.23		£66,928.14
11/15	£27,800.00	£40,629.08		£465.00	£950.00		£69,844.08
12/15	£150,115.00	£240,710.62	£45,226.00	£45,420.81		£19,991.00	£501,463.43
2016							
01/16	£76,198.00	£63,654.06		£35,079.00			£174,931.06
02/16		£62,688.15				£29,017.33	£91,705.48
03/16	£108,022.00	£73,479.52		£1,500.00	£2,077.84	£382.67	£185,462.03
04/16		£62,630.05		£6,663.81		£492.27	£69,786.13
05/16	£73,862.00	£121,971.92		£7,750.00	£17,361.16	£27.45	£220,972.53
06/16		£222,950.87					£222,950.87
Grand Total	**£899,123.91**	**£2,049,615.64**	**£63,801.00**	**£119,844.61**	**£31,352.65**	**£71,133.13**	**£3,234,870.94**

9 Intellectual Property Rights (IPR) [CONFIDENTIAL]

VISOR complies with the Ofgem default position regarding the IPR ownership.

Throughout the project, the supplier, GE Grid Solutions, generates new Intellectual Property in the form of WAMs detection and analysis applications. The supplier will retain the IPR which they independently create.

No further IPR has been generated or is expected to be generated.

10 Other

11 Accuracy Assurance Statement

I therefore confirm that processes in place and steps taken to prepare the PPR are sufficiently robust and that the information provided is accurate and complete.

Signature: ___________________

Name (Print): ___________________

Title: ___________________

Date: ___________________

Signature: ___________________

Name (Print): ___________________

Title: ___________________

Date: ___________________

12 Appendices

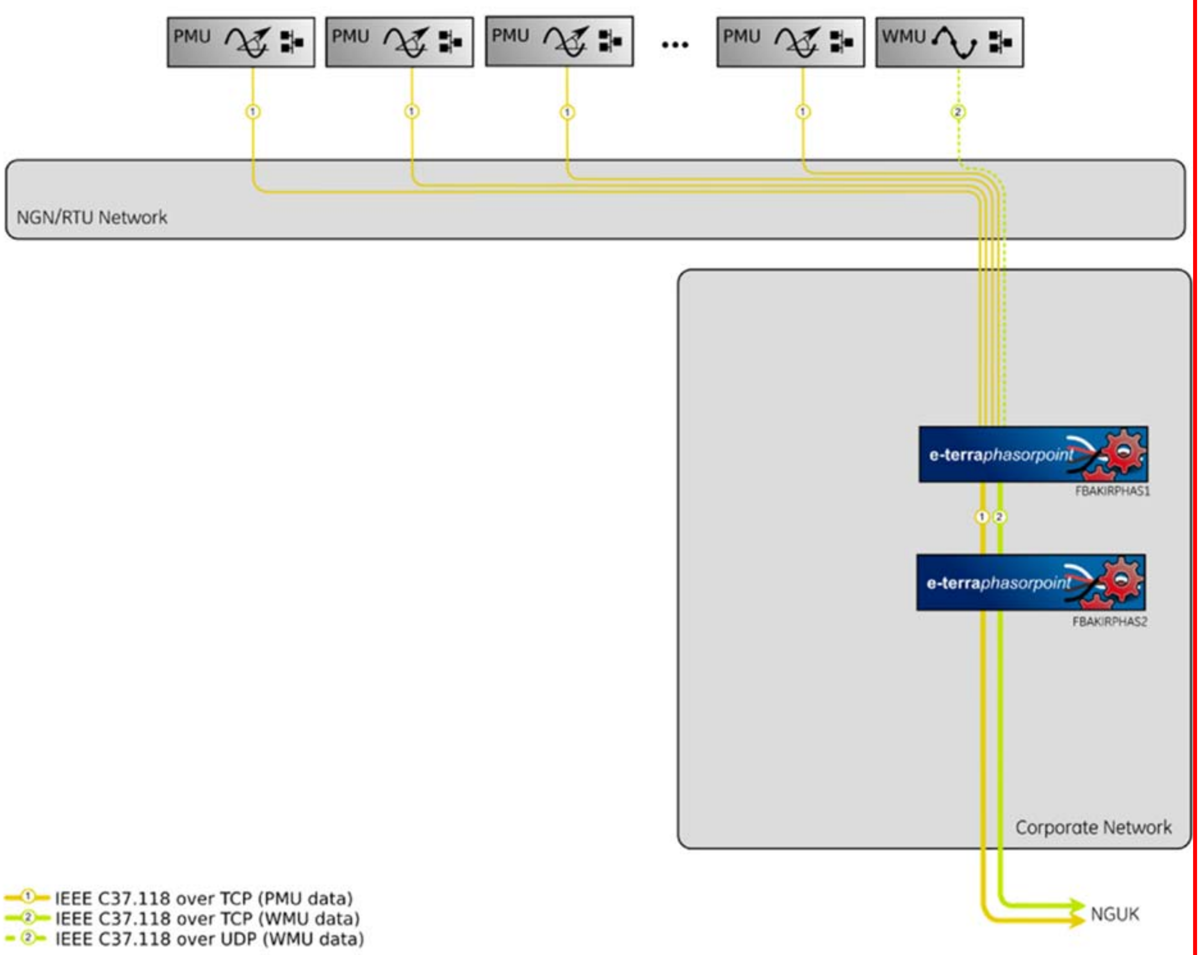
12.1 Appendix 1 Bank Statement

Account information:				Balance information as of 15/06/2016	
Sort code	83-07-06	Account type	SPECIAL INT BEARING	Last night's ledger	4,369,528.70 Cr
Number	12755654	Bank name	Royal Bank of Scotland	Start of day ledger	4,369,528.70 Cr
Currency	GBP	Branch name	GLASGOW CITY BRANCH	Today's ledger	4,369,528.70 Cr
Alias	SP TRANSMISSION PLC	Paper statement produced	13/05/2016	Last night's cleared	4,369,528.70 Cr
Short name	SP TRANSMISSION PLC	BIC	RBOSGB2L	Start of day cleared	4,369,528.70 Cr
IBAN	GB02RBOS83070612755654			Today's cleared	4,369,528.70 Cr

12.2 Appendix 2 Technical description of Sandbox (Confidential)

Currently, WAMS data produced by the SPEN PMUs and WMUs is received via the "NGN" network and collected in the **e-terra***phasorpoint* systems located in the corporate SPEN networks. Two **e-terra***phasorpoint* systems are operational in this network; the original PhasorPoint system (FBAKIRPHAS1) which acts as the primary receiver of WAMS data and the new SPEN VISOR system (FBAKIRPHAS2), which acts as a demonstration platform for the VISOR applications.

Data is sent from the SPEN VISOR system to the National Grid VISOR data hub as part of the VISOR project. The current WAMS data flow is schematically shown in Figure 1.



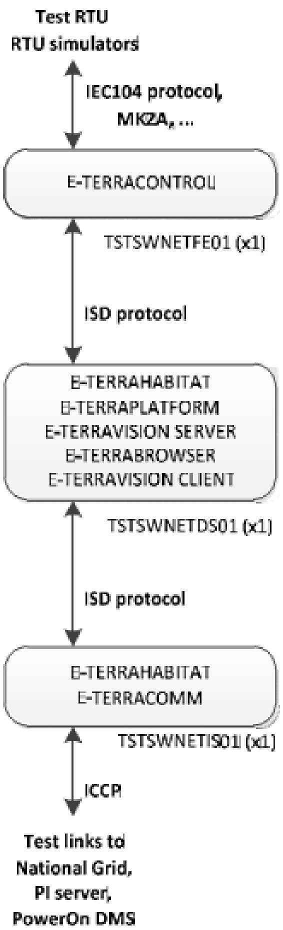
Current Data flows used in the VISOR Project

The design of the WAMS-EMS Demonstration System is based on the principle of extending the current systems (both EMS Sandbox and VISOR WAMS) to meet the aims of the new demonstration system. This should minimise additional infrastructure requirements. The WAMS- EMS demonstration environment will be a single availability system.

The architecture of the EMS Sandbox environment is similar to production system, with the except that:

- There is no redundancy (a single availability system)
- There are no workstations
- There are no domain controllers
- There are no web servers (for FAT/SAT connection was done using Remote Desktop).

The following diagram is a simplified overview of EMS Sandbox system.



Schematic showing component relationships in the current Sandbox EMS

New SANDBOX WAMS server

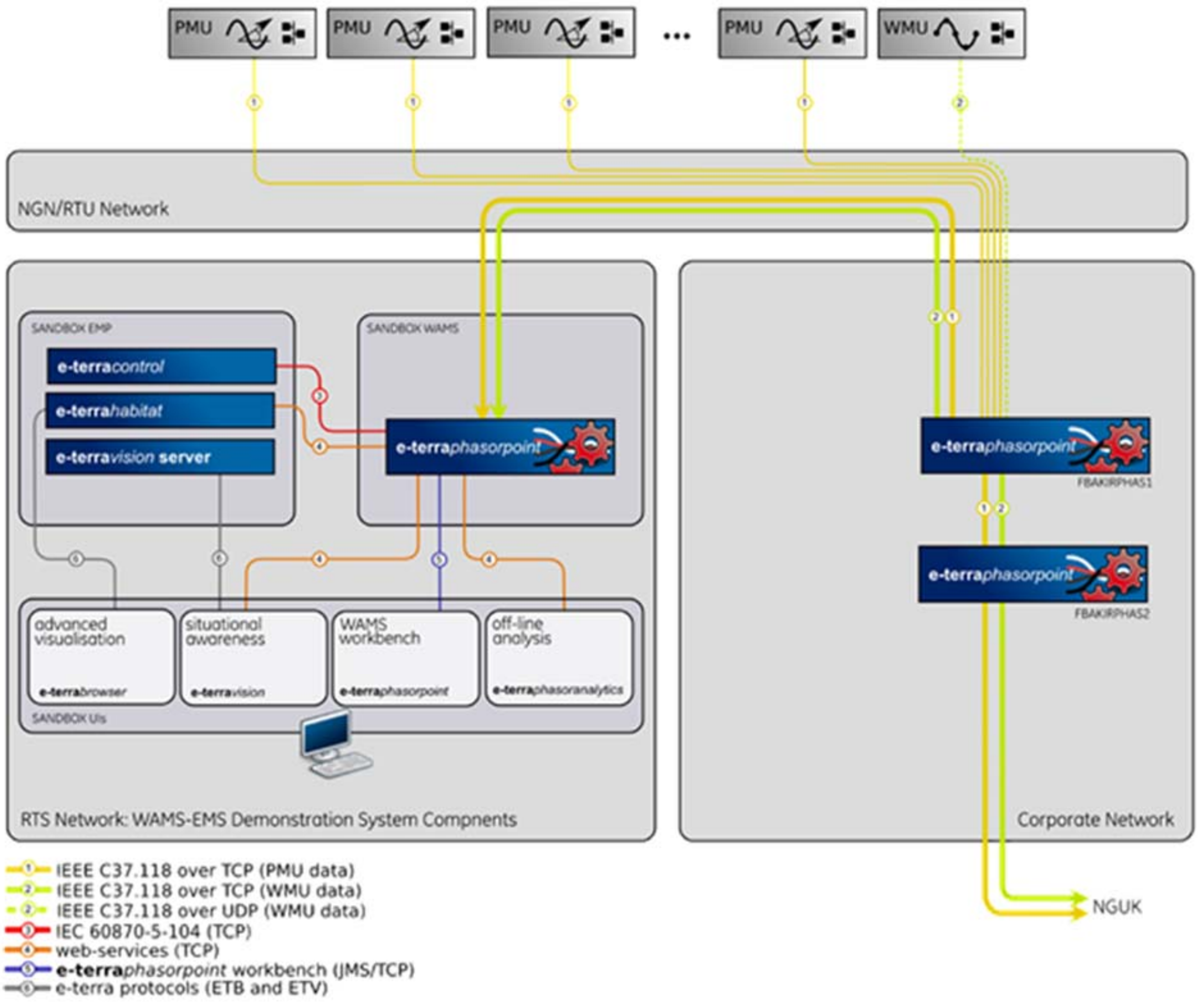
A new dedicated e-terraphasorpoint server (SANDBOX WAMS) will be required, and located in the Sandbox environment of the RTS network. This new e-terraphasorpoint SANDBOX WAMS receives all the WAMS data and replicates the advanced WAMS application processing currently being performed by the Production WAMS and VISOR WAMS system (see Section 4.1). This replication allows application results and alarms to be provided to other components within the WAMS-EMS Demonstration System.

Data Flow: WAMS data into the RTS Network

WAMS data currently arrives via the NGN Network from IDMs/PMUs and WMUs distributed across the network using the IEEE C37.118 protocol. The e-terraphasorpoint Production server PDC (FBAKIRPHAS1) concentrates the data and transmits this as a concentrated stream to the e-terraphasorpoint VISOR server (FBAKIRPHAS2)for processing.

Two new IEEE C37.118 output stream TCP services will be configured in the e-terraphasorpoint PDC (FBAKIRPHAS1) to provide the consolidated 50Hz PMU data and consolidated 200Hz SSO data respectively.

The new dedicated e-terraphasorpoint server (SANDBOX WAMS) will initiate a TCP connection to the output stream service ports on the e-terraphasorpoint PDC (FBAKIRPHAS1) in the corporate network to start the WAMS data flows (figure below).



Key WAMS-EMS Integration Components and Connections

Training

A primary intention of the WAMS-EMS Demonstration System is to enable familiarisation of SPEN operators and other key control room personnel with the use of e-terraphasorpoint in an integrated WAMS-EMS environment.

A number of initial training sessions shall therefore be held, to introduce the core principles, functionality and hands-on usage of the integrated WAMS-EMS software. Repeated sessions shall be arranged to allow for availability of SPEN personnel. The following topics shall be covered

Training Topic	Format	Duration	No. sessions
Introduction to WAMS concepts	Classroom	⅓ day	3
Introduction to use of **e-terra***phasorpoint*	Classroom with practical examples	⅓ day	3
Use of WAMS in improving real-time Situational Awareness	Classroom with practical examples	⅓ day	3
WAMS data integration using Grid Stability Assessment (GSA) tools [OPTION], alarm integration and State Estimation	Classroom and practical examples	½ day	3
Historical phasor analytics capabilities using **e-terra***phasoranalytics*	Classroom and practical examples	½ day	2
Training for IEC 60870-5-104 configuration for State Estimation and integration	Hands-on	½ day	2
Typical software configuration and system administration tasks pertaining to Sandbox	Hands-on	1 day	1

Connection between EMS Production and Sandbox System

Providing live data into the new WAMS-EMS Demonstration System is a critical requirement for supporting the environment. Having a direct ISD connection between EMS data servers offers flexibility in that data can be exchanged both ways between production and Sandbox if required in the future.

Configuration of IEC 60870-5-104

The SANDBOX WAMS system will be used to demonstrate the transfer of data and alarm information to the EMS system using IEC 60870-5-104. A set of 5 signals will be configured to demonstrate both data and alarm transfer. In addition, these signals will be used as the basis for training on how to perform this configuration. This training will ensure SPEN can autonomously expand IEC 60870-5-104 transfer as required.

The e-terraphasorpoint system operates as an IEC 60870-5-104 slave service (default TCP port 2404).

Configuration of Situational Awareness Clients

The new SANDBOX WAMS system will have a web-service configured, able to provide WAMS alarms and data directly to the e-terravision client systems. SPEN will need to ensure at least one workstation with e-terravision installed is available within the WAMS-EMS Demonstration system. The workstation(s) should have sufficient resources (including high resolution screens) to support e-terravision, e-terraphasorpoint workbench and e-terraphasoranalytics client applications operating simultaneously.

Version 4.0 of e-terravision will be supported. The e-terravision client applications require network access to the EMP e-terravision server (default TCP port 5002) and to the e- terraphasorpoint server live ETV web-service (default TCP port 24721).

Configuration of Grid Stability Assessment (GSA)

The new SANDBOX WAMS system will have the option for integrating WAMS data directly into the e-terrahabitat engine, for display of specific WAMS alarms and data within e-terrabrowser using the Grid Stability Assessment engine. The GSA version 1.0 engine provides the following additions to the e-terrabrowser advanced visualisation application:

- WAMS status alarm overview (overview of WAMS alarms)
- Modes display, listing defined WAMS modes, showing mode frequency and damping ratio
- Angle differences, lists the defined angle differences, showing angle difference in degrees, alarm status, and distance from limits
- Corridor Flows, lists the defined corridors, showing MW and MVAR, alarm status, and distance from limits

In addition, GSA provides a direct interface with the e-terrahabitat ALARM application, and issues WAMS mode and disturbance alarms.

Enhanced Off-Line Analytics

e-terraphasoranalytics is a client application that provides access to WAMS historical data for advanced trending and analysis. Version 1.2 (beta) will be provided, which provides the following key features:

- e-terraphasorpoint historical data navigation and selection interface
- Post-event analysis and charting
- Correlation analysis (Power spectral density, coherence and cross spectral density)
- Ringdown analysis
- Baselining, for analysing system modal oscillations
- COMTRADE synchrophasor data import
- Download of data to local storage for off-line analysis

For e-terraphasoranalytics to access historical phasor data, it requires network access to the e-terraphasorpoint historical web-service (default TCP port 24721).

As well as forming part of the Demonstration System, the e-terraphasoranalytics client software can also be configured to connect to the existing e-terraphasorpoint servers located at SPEN, with appropriate license changes. This would allow e-terraphasoranalytics clients to be located in the corporate networks and connect to the VISOR or production e-terraphasorpoint systems (FBAKIRPHAS2 and FBAKIRPHAS1 respectively).

New e-terraphasorpoint SANDBOX WAMS System

The e-terraphasorpoint license for the SANDBOX WAMS System shall mirror the features enabled under the current VISOR license, adjusted to enable historical web-services. This shall be applied to a single instance of e-terraphasorpoint in the demonstration environment.

New Off-Line e-terraphasoranalytics Application

The following license shall be granted for the e-terraphasoranalytics software provided in association with the SANDBOX WAMS System

e-terra*phasoranalytics* **WIDE AREA MONITORING SYSTEM SOFTWARE**
e-terra*phasoranalytics* software • 670 phasors • 5 clients[(1)]
e-terra*phasoranalytics* Interfaces • **e-terra***applications* interface (to access data from **e-terra***phasorpoint* Historian) • COMTRADE synchrophasor data import
e-terra*phasorpoint* Applications • Time Domain Analysis • Frequency Domain Analysis • Modal Ring-down Analysis • Dynamic Performance Baselining

12.3 Appendix 3 Project Risk Register (Confidential)

12.3.1 Active Risks

Risk No	Risk Category	Risk Description (There is a risk to the project…)	Potential Impact	Risk Owner	babi	anci	utat	erall	Control Measures	babi	anci	utat	erall	Action Taken and Updates
WP230 315-03	Installation	**Delays in commissioning SAT for WAMS and communication link with no expected or firm connection date**	**SHETL's progress in installation and commissioning two PMU and one WAMS within their network poses direct risks to SDRC 9.5.1 Delay incurred in gathering and analysing PMU data also deteriorates data analysis activities**	PDT	10	4	4	18	Ongoing support from other project partners and learning from other TOs. Support SHETL IT in configuring communication routing.	1	4	3	8	PDT 22/10 - Contingency plan enacted and arrangements underway to establish IPSec link between SPT and NGET. Due Dec'15. PDT 30/03: Kintore OK, Beauly unsynchronised requiring site visit by CN, GE awaiting VPN access.
	Rollout	**The Roadmap Report may not capture requirements from both TO and SO perspective.**	**If Business Cases not sufficiently supported, it will hinder ability to transition from innovation Proj to business.**	PDT	5	2	8	15	Ensure expectations of report are defined and understood. Closely manage the development of the report, with early review of draft.	1	1	8	10	
	Testing	**Deliver of Sandbox test facility delayed beyond Q3 2016.**	**Reduced time using , demonstrating and testing the facililty. Chance of project overrun.**	PDT	7	2	5	14	Engage with IT and procurement from outset. Seek quickest procurement route. Configure Firewalls etc in paralell / ahead of site work.	3	1	5	9	
WP	Installation	**Establishing communication links between Datacenters in Scotland and England:**	**Multifaceted risk to delay project programme; Lead time and complexity in provisioning communication links with multiple vendors; Lack of coordination between IT departments between TOs to design and deliver communication infrastructure; Coordination of service providers in commissioning network links due to contractual constraints causing delays of installation**	NH	5	4	3	12	Closer coordination between project partners to ensure IT departments are engaged ahead of schedule to minimise possibility of future delays	1	4	3	8	Learning taken forward for future installations, in particular at SSE PDT 30/03: SSE awaiting SAT. SPT-NGET MPLS is live but stream not currently live due to indexing/historical transfer delay. Plan: get real-time data stream running 1-2wks, then focus on historical data.
WP230 315-01	Coordination	**Coordination of project partners to the project programme.**	**The ongoing commitment of SHETL to the project raises concerns as to their ongoing involvement and support for the project objectives.**	PDT	3	4	4	11	Continual support and assistance shared amongst project partners to ensure project programme remains sound;	1	4	3	8	Regular (Weekly) meetings held with PDT team to discuss progress and raise issues. Contingency plans to install units at northern-most site in SPT should SSE fail to deliver.
WP17	WAMS Performance issues	PMU data quality issues, or PMU/PDC data integrity issues (gaps)	Application value reduced	PA	4	3	2	9	Require proof of prior installations with good data availability. Use existing PMUs that have evidence of acceptable practical performance, and standards compliance where possible. Applications to be robust to data packet loss.	1	1	1	3	PDT 24/09 SC to send KS an update on this Should be closed in jan once report done PDT 30/03: SPEN DQ patch applied late'15 working well. Monitoring ongoing.
WP7	Coordination	Potential lack of co-ordination of VISOR with NG DSA project. Dynamic Security Assessment to define real-time critical MW and angle difference from simulation should be co-ordinated with VISOR to use the synergies.	Without co-ordination, the ability of TSAT to create angle difference and MW thresholds, and the ability to use these in VISOR will not be demonstrated. Further work will be required beyond VISOR to demonstrate the synergy.	Fan Li	4	3	2	9	(1) Ability to interface DSA limits (from Powertech TSAT) with WAMS in a power/angle display, with contingency analysis, will be demonstrated by the supplier, this is now a requirement of the future roll out (2) the TSAT operating points and limits will preferably be linked to the VISOR server at National Grid, but if this is not practical, the benefits of integration will be assessed by off-line data review from both systems. (3) If TSAT results are not available in the timeframe, MW and angle limit values will be	2	1	1	4	PDT 24/09 - Fan Li is dealing with this
NT1809	New equipment	B6 boundary display application not precisely defined and requires collaborations between proj partners	Delays / Unsatisfactory application	GE	5	2	2	9	Each project partner needs to take ownership of this from their end to ensure deadlines are met	2	2	2	6	NGET to examine benefits of application's use, based on measurement data

SP ENERGY NETWORKS

Risk No	Risk Category	Risk Description (There is a risk to the project...)	Potential Impact	Risk Owner	babi	anci	uat	erall	Control Measures	babi	anci	uat	erall	Action Taken and Updates
PR10	Commercial	Late delivery and delays to programme.	Project Delay	PM	3	2	3	8	Pro active Project Management. Contractual incentives to keep to programme i.e. liquidated damages. Financial incentives to keep to programme i.e. retention and milestone payments.	3	3	3	9	22/5/14 Cblenk: Contract negotiations are deliver by incentivising the supplier to deliver on time
NT24	Security	If the SO network model is provided to Manchester University is may contain confidential data	NG could mistakenly send confidential data outside of the Organisation	PA	2	1	5	8	Ascertain if the model is capable to be reduced, and can still provide the correct level of granularity for UoM. Or allow UoM to work from NG premises in Wokingham	1	1	1	3	PDT 24/09 - Reduction not suitable so more mngt is required when releasing model information. Ongoing Risk
NT	Data	Server performance with increased data volumes	Performance impact of new applications on server load may be heavier than anticipated.	Psymetrix/PDT	3	3	2	8	The performance of the servers need to be monitored on a continual basis as more WMUs are installed on the network·				0	
NT	Data	Configuration of data transfer and firewall (IT infrastructure)	Delays in receiving WMU data may impact on ability to capture system events. Substantial delays may impact analysis and reporting deliverables.	PDT	3	3	2	8	Closer coordination between project partners to ensure IT departments are engaged ahead of schedule to minimise possibility of future delays				0	
NT12	Substation Outage	Lack of appropriate outage required for installation or commissioning of the equipment resulting in an Inability to obtain the relevant outages for installation or commissioning	Possible delays to commissioning programme	PM	2	3	3	8	Outages identified and incorporated in Scheme Requirement Document (SRD). A second phase installation has been designed in Year-2.	1	3	2	6	JY 26/05 Two installation phase are built in the project plan to allow for Outage times within all TO area's. Existing outage plans for all TO's will be used for planning installs PDT 24/09 - Still considered High Risk
PR1	Resource	There is a risk that the project cannot secure adequate internal and external resource and specialist people against project plan.	Project continuity disrupted by resource churn and lack of consistent resources. Program delayed due to insufficient resources	PM	3	3	2	8	A project resource plan to be developed by the PM/PMO. Review and update resource plan regularly by PM/PMO.	2	2	2	6	JY 26/05 SPT have requested external support (consultants) to cover the legal and tendering aspects PDT 24/09 - Ongoing risk
NT4	Delayed Software Development	Supplier fails to produce fit-for-purpose software on time.	Significant delays to Project	PM	3	3	2	8	Contract clauses in place to protect Project Owners financially in terms of delayed manufacture and to give incentives/punish manufacturer to remain on target with production. Ensure sufficient resources in place to deliver the key parts of the function development	2	2	2	6	PDT 24/09 - Regular Project plan reviews to be carried out. Continual risk to be left on register PDT 23/02 - Doscussed and agreed to remain on reg.
WP230315-02	Security	Commercial sensitive information from reports and presentation poses a risk, be aware of confidentially in reports and presentations e.g. System Design.	Information from project documents could be used for other purposes	PDT	1	3	3	7	Ensure information that goes into public domain is an edited version.	1	1	1	3	
NT	Data	Data quality and availability affecting accuracy and development of applications (VLF and LF Source Location)	Data quality and availability issues may make detection of background oscillations difficult, however raised amplitude events will still be detectable.	Psymetrix	4	1	2	7	Improved quality data will mitigate the effects	1	1	1	3	Firmware upgrades to network and substation equipment applied, and appear to be significantly reducing data loss.
NT	Comms	Provision of necessary Service Provider	Delays in establishing communcations link may impact on ability to capture system events. Substantial delays may impact analysis and reporting deliverables.	PDT	2	3	1	6	Closer working and involvement of the service providers to ensure they understand the requirements and purpose of these new applications.	1	3	1	5	The IS needs and prioritisation of Smartgrid solutions like VISOR are still evolving in terms of service level agreements and flexibility within the incumbent service providers.
NT13	Costs	Project costs higher than anticipated due to unknown or unforeseen costs	Project budget exceeded	PM	2	3	2	7	Monitor costs and forecasts regularly and challenge all spend.	1	2	2	5	PDT 24/09 - Ongoing Risk
WP		Ongoing prioritisation for system access to install monitors and modify existing PMUs:	Installation and modification of hardware in transmission substations typically require an outage, and therefore need significant advanced planning to ensure delays are kept to a minimum.	PDT	3	3	1	7	Sites works are arranged to piggy-back on ongoing schemes to manage system access restrictions.	3	3	1	7	
WP		Delayed acquisition of measurement data affecting report deliverables:	Delays in receiving historical phasor data from project partners may lead to delay in production of reporting analysis.	PDT	3	2	2	7	Ongoing dialog with project partner IT personnel to streamline data transfer process.				0	
WP3	Data conversion for State Estimation	Data supplied to the study may be in proprietary form and require conversion	Delay in work stream.	Phil Ashton	4	2	1	7	Include contingency for data reading/conversion. No critical dependency, other than roll-out requirements, much later in project. However, it is noted that there is an advantage to an early indication on whether PMUs should be integrated in an EMS refresh. Early indicative results can be obtained using a smaller subset of data, e.g. based on the SPTL network. PDT 24/09 - UoM will have their own phaser point and will attend training	2	1	1	4	PDT 24/09 - UoM will have their own phaser point and will attend training

Risk No	Risk Category	Risk Description (There is a risk to the project...)	Potential Impact	Risk Owner	bab	anc	uta	eral	Control Measures	bab	anc	uta	eral	Action Taken and Updates
WP 180 914-2	Firewalls	Firewalls prevent WMU data from arriving at the servers	SAT delayed pushing project back	PDT	2	3	2	7	Each project partner needs to take ownership for data accessibility and security management				0	
WP 2	Hybrid State Estimator complexity	If adding phasors to SE increases complexity, there is a new risk of SE failure with phasors, balanced against reduced risk with redundant data.	Negative outcome for roll-out	PM	2	2	2	6	(1) HSE process is applied outside the operational environment so no risk is introduced by the project. (2) Ensure that sufficient pre-processing of PMU data is applied so that bad data and dynamic changes are filtered prior to inclusion in the HSE, to avoid degrading the HSE result (3) Trial in a commercial SE environment to give realistic comparison of SE vs.HSE results to demonstrate and quantify the effect on robustness, thus quantifying the true risks (4) Make judgement of relative benefits of PMU data either as independent cross-check of conventional SE compared with integrated HSE process, to inform roll-out plan.	2	2	1	5	JY 26/05 Hybrid State Estimator finding will inform the future roll out specification not justify it so this risk is no longer applicable.
WP 22	Laboratory accommodation	Change of equipment's, laboratory refurbishment	No access to the equipment for certain preferred time	Vladimir Terzjia	2	2	2	6	Joint planning with the academic partner, awareness of the mid-long term strategy of the School/ Department	2	1	1	4	PDT 24/09 - Measures being taken for RTDS to be moved. PDT 23/02 - PW confirmed Lab has already moved twice since start of project, no issues.
WP	Rollout	Integration of innovation into business as usual activities:	Uncertainty surrounding the true benefits of phasor information will hinder the roll-out into BaU	PDT	2	0	4	6	Benefits of phasor meansurements must be thoroughly assessed and reported upon; Internal knowledge dissemination throughout vital to ensure benefits of project are widely known				0	
PR5	Project program	The current project plan has little contingency. The project plan has been extended to manage other risks and uncertainties, leaving little float for unforeseen events	Project schedule delay, due to unforeseen events	PDT	1	3	1	5	Regular review and update of project plan ensuring all up to date information is included and the impacts studied and float identified where possible.	2	2	2	6	22/5/14 CB Lenk: Project Plan is reviewed and updated each month. PDT 24/09 - Ongoing. Regular review required
NT15	Strategic Spares Policy	Spares Policy for new technology may not be suitable when taking all risks into account	If suitable spares are not identified and available, the risks of losing the PMU/PDC in the network may ultimately result in failure of the project.	PM	1	2	1	4	Installation of test blocks.	2	2	2	6	JY 26/05 Spares are being supplied as part of prospective contract with preferred supplier. PDT 24/09 - Spare units identified. Continual risk to be left on register. PDT 23/02 Short & Long term strategies to be looked at for spares.
NT	Testing	Limitations laboratory access to PMU types (Hardware and Firmware):	Analysis at UoM uses different models of WMUs and PMUs. Learning from laboratory testing may differ from the equipment installed on the network.	UoM	2	1	1	4	PDT consider this to be a minor concern and will review on ongoing basis				0	Concern raised and will be assessed once sufficient data has been gathered from the 3 TOs
NT21	New equipment	Lack of experience and knowledge regarding new pieces of equipment	H&S risks present as a result of lack of experience. Inefficient working, errors and high costs could result	PM	2	1	1	4	Specialist tools and training required for maintenance activity. Procedures to be developed.	1	1	1	3	JY 26/05 Supplier's support during the installation, and training for using the devices have been specified as part of Tender Process PDT 24/09 - Training in place to satisfy this PDT 23/03/ - SAT's traning to be included.
NT	Testing	Constraints on Size of Laboratory Test Signals:	The size of the signal files that can be played back using the Omicron software (Advanced Transplay) is limited, and may limit the range of cases that can be used to test the devices in the laboratory, particularly when attempting to capture fast system dynamics.	UoM	2	1	1	4	PDT consider this to be a minor concern and will review on ongoing basis				0	
PR12		Intreaction with PMU manufacture						0					0	

12.3.2 Closed Risks

Risk No	Risk Category	Risk Description (There is a risk to the project...)	Potential Impact	Risk Owner	Probability (1-5)	Financial Impact (1-5)	Reputation Impact (1-5)	Overall Risk Score	Control Measures	Probability (1-5) 2	Financial Impact (1-5)3	Reputation Impact (1-5)4	Overall Risk Score 5	Action Taken and Updates
WP		Skilled resource availability:	Restrictions on developer and test resources at Psymetrix for software application development	Psymetrix	5	3	3	11	Key functional requirements will be developed first to meet OFGEM SDRCs; Additional developer resources sought; Use of Edinburgh Power systems team staff to assist with testing; GUI implementation is very resource intensive, new applications could be demonstrated earlier via an off-line tool run in Matlab.				0	Closed: Have recruited Alstom developer to support Edinburgh office
WP	Installation	Delays in commissioning of communication link between SPT and NGET, and inability to escalate BT for delays in commissioning network links (via Verizon)	Pro-active monitoring and potential loss of data for a period of time and burn additional resource time to remediate the connections	PDT	4	2	4	10	Delays have been escalated as far as possible with BT. Mitigation by deploying IPSec link as interim solution until MPLS link is online.				0	Closed: MPLS link commissioned on 29/02/16
WP 16	Supplier of TO/TSO delay on Base Install	Delays in implementing VISOR platforms and communications routes to PDCs	Project delay	SG	4	3	2	9	taken from planning studies Select vendor with track record of commercial WAMS installations. Supplier must have experience of deploying in utility environment. Direct support by supplier via VPN for diagnosis. Comprehensive training by Supplier for IT personnel in all 3 partners in IT requirements of WAMS project.	2	2	1	8	Closed: base installs and communications links complete
NT2	Tech Spec compliance	Technical Specification not met as a result of unrealistic requests or errors made by a stakeholder Manufacturer/Supplier might not be able to meet all requirement& Acceptable non-compliances and some non acceptable non-compliances	Installation may be postponed resulting in unnecessary delays, or unsuitable technology may be installed with the inherent risk of technology failure or network instability	PM	2	3	3	8	Assess technology in accordance with the type registration process to ensure compliance with the Tech Spec. Identify and resolve non-compliances	1	1	2	4	JY 26/5 Risk Closed. Supplier has confirmed that all the Tech Spec can be met. (Following a full Tender process provided some information on potential suppliers to meet the requirements of the Tech Spec) The Tender response has covered type testing and there were no non-compliances identified in successful tender submission.
NT1	Technical Specification (Tech Spec) preparation	The Technical Specification is either too abstract or descriptive such to hinder development. Errors within the Tech Spec could lead to problems	Specific problems may not even be accounted for due to ambiguous specification, else ingenuity of supplier may be prohibited. A substandard Tech Spec could lead to omissions from the Tech Spec and/or the technology not being suitable for the system	PM	2	5	3	10	Produce a Tech Spec which has had input from all relevant business areas including a suppliers review of the Tech Spec, giving headroom for supplier to provide innovative solutions. Carry out full analysis of system using Tech Spec data, including power flow analysis, and any related effects Spec of the new technology.	1	2	2	5	JY 26/5 Closed Risk - materialised now that technical element of tender is complete. A full analysis for the system using the Tech Spec data was not required ad the project were advised by SO that there are no material changes to loads flows expected in next 3 years.
WP 1	Project Outcome	The outcome of the project may show insufficient benefit of HSE to justify roll-out, or inconclusive results i.e. the accuracy & robustness improvement does not justify the deployment cost. Outcome of marginal benefit of Capacity Enhancement with Hybrid State Estimation	Negative outcome for roll-out	PM	4	2	1	7	(1) Risk of negative or inconclusive results reduced by application to a subset of the network (B6) that is well monitored and where PMU data expected to provide a benefit. (2) If HSE is not justified, then revise goals to use PMU as a cross-check or validation of the SE results, flagging inconsistencies, rather than migrating to an HSE approach. Note that a negative outcome helps to define TO/SO strategy, and is not a project failure.	2	1	1	4	JY 26/05 Hybrid State Estimator finding will inform the future roll out specification not justify it so this risk is no longer applicable.
WP 9	Centralised application not commercially available	While SSO detection is applied locally in commercially available equipment, there is no wide-area co- ordination and system view. Details of communications protocols and interfaces still to be addressed.	Delay of integration of SSO	PM	4	4	3	11	(1) Specific details of interface to be stated by equipment vendor in tendering stage. (2) WAMS system should be proven to be capable of managing non-phasor data, so SSO integration not a major change (3) Interim use of manual data transfer if necessary to capture SSO behaviour before integration	2	2	1	5	JY 26/05 Risk is no longer applicable as all control measured were carried out as part of technical element of Tender process. Project team are happy with technical submission from supplier. Risk closed.
WP 14	ROCOF Trip Risk Indicator application not commercially available	Visualisation of regional variation and measurement change variation of RoCoF and consequence for DG tripping is not commercially available, and will need to be developed.	If feature not delivered, regional impact of disturbance on ROCOF will not be visible. Opportunity for learning outcome relating to ROCOF setting missed.	PM	4	2	1	7	(1) Supplier to commit to delivering application (2) If not delivered (or delivered late), ensure that data is available for off-line study to investigate ROCOF performance.	1	1	1	3	JY 26/05 Risk no longer applicable as taken as option with supplier during ender process.
WP 21	Researchers' expertise	Lack of appropriate PDRA working on the project; or the VISOR project may not be on the top of the priority list of the research team at academic partner	Delay of the key elements delivery	PM	3	3	2	8	Start the recruitment of dedicated PDRA; with appropriate clause within the collaboration agreement to enable an alternative arrangements, such as outsourcing, re-tendering for the elements	2	2	2	6	JY 26/05 Risk closed as University of Manchester have resource in place