# Investment Decision Pack

# NGET_A7.07 System Monitoring

# December 2019

As a part of the NGET Business Plan Submission

nationalgrid

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| Justification Paper<br>Load Related – System Monitoring | | | |
|---|---|---|---|
| **Primary Investment Driver** | Licence obligation to provide the ESO system information in compliance with STC-P 27-1 | | |
| **Reference** | NGET_A7.07 System Monitoring | | |
| **Location in Submission Narrative**** | Chapter 7 – *Enable the ongoing transition to the energy system of the future*<br>Section 5.3 i) *Optimise with the ESO through a new mechanism to reduce whole system costs and installation of system monitoring to allow for zero-carbon operation by 2025* | | |
| **Cost** | £50.35m (TOTEX) | | |
| **Delivery Year(s)** | 2021 – 2026 | | |
| **Reporting Table** | B series tables and totex cost matrix tables | | |
| **Outputs in RIIO-T2** | National roll-out of system monitoring in accordance with STCP 27-1 | | |
| **Spend Apportionment** | **T1** | **T2** | **T3** |
| CAPEX: | £8.43m | £48.026m | £0m |
| OPEX: | | £2.325m | |
| Total: | | £50.351m | |

**All costs are in 18/19 prices, unless otherwise stated.*
*** OPEX costs are covered in the annex NGET_A14.17_Total Opex*

## Contents

# 1. Executive Summary

The rapidly changing low carbon generation mix and increasingly active distribution networks, requires both the ESO and transmission companies to improve their ability to operate efficiently under this massive network change in network behaviour. A failure to be able to observe and then model accurately these changes in network dynamic behaviour will significantly contribute to a higher likelihood of wider system disturbances and possible blackouts, having a massive economic consequence for consumers.

The ESO has established a new policy STC-P 27-1 which mandates all the TOs to install synchronised system monitoring at all their substations to improve the wider system observability by the end of T2. System Monitoring services are critical to validating the assumptions used in planning, operation and management of the Transmission System and its assets. SM provides information on disturbances, power quality and faults which will enable ET to observe the performance of its assets and the network and also identify emerging risks.

An investment of £48.026m (+ £[redacted]m OPEX) will enable us to comply with this licence requirement and provide a resilient end to end supported service, making sure that both the data and analysis of network performance can be captured and provided in a timely manner.

The existing system monitoring equipment and delivery infrastructure is not fit for this new purpose, requiring new synchronised monitoring equipment and automated data retrieval to deliver this service to a central place.

Three options have been considered, the selected strategy provides a compliant approach which utilises existing plant and equipment where possible to minimise the cost and impact on network outages and deliverability. The costs have been based on the tenders, learning and experiences gained from T1 innovation schemes.

# 2. Context and need case

System Monitoring (SM) is a critical tool in the effort to understand and manage system resilience. The capability to provide a secure network is reliant on confidence in understanding how the system will respond to different contingencies. This is becoming increasingly difficult to determine without better system visibility and modelling validation. This is necessary to observe wider network behaviour and spot emerging system disturbances, which if not checked can worsen and increase the likelihood of major system disturbances and ultimately wide scale power blackouts. This can only be provisioned through a synchronised system monitoring service taking measurements across the whole transmission system.

The ESO document, System Operability Framework (SOF) highlights the many concerns including the growing complexity of the system, the need to be able to coordinate operations between the TO and DNO more effectively. SM is the enabler for us and the SO to characterise the dynamic behaviour in lower voltage networks to an observable level, which can be modelled and used to validate Power System studies.

Following a number recent system faults ([redacted], [redacted], [redacted] & [redacted]), where a number of events occurred together, there was insufficient accurately timed measured evidence to adequately support post fault investigations. SM data plays a significant role in supporting the conclusions to system performance reporting.

The Electricity System Operator (ESO), has established a new policy called System Performance Monitoring Procedure (STC-P 27-1) which defines the service level it requires from the TOs to provide adequate system visibility and disturbance reporting across their respective sectors of the GB network.

The Policy was approved in Oct 2018 and went into operation Feb 2019. This requires significant investment and network intervention to be fully in place by the end of T2.

The present SM capability was designed and installed when the network was more stable and predictable (consisting of large scheduled synchronous generation). This capability needs to be upgraded and enhanced to provide the accuracy and resolution necessary to both observe network behaviour and validate the modelling to support network planning for ETO while delivering the quality of service the SO policy mandates.

## 3. T1 experience and lessons learned

As the volume of renewable and converter based generation and load has increased it has become more evident that the existing SM is not fit for purpose.

***Innovation projects***

During T1, the strategy for a new and appropriate solution has been developed through a number of Network Innovation allowance (NIA) and Competition (NIC) projects. The key activities being:

- **Visualisation of Real Time System Dynamics using Enhanced Monitoring** (VISOR). The project, led by SPEN with all the TOs and the ESO delivered a proof of concept Wide Area Monitoring System (WAMS) using phasor measurement units (PMUs) to measure sub-synchronous oscillations associated with series compensation and HVDC connections. The platform is a proprietary system called Phasorpoint (GE) and is currently the only tool capable of visualising the PMU data.
- **Enhanced Frequency Control Capability** (EFCC), led by the ESO, utilises resilient PMU data to develop new, significantly faster response solutions utilising renewables, demand side resources, and other new technologies in a coordinated manner. The successful implementation of this project can result in savings of £150m-£200m per annum by 2020.
- **Transmission & Distribution Interface 2.0** (TDI 2.0) is a SmartGrid based initiative which aims to develop technical and commercial solutions to maximise the use of distributed energy resources (DER) to resolve transmission voltage constraints. In addition, it will develop a Distribution System Operator (DSO) route to market for such solutions in a coordinated manner with the existing System Operation functions.

***Capital Schemes***

The following schemes, shown in Table 1, are predominantly system monitoring equipment and run through T1 and T2.

| Title | T1 (£k) | T2 (£k) | Total (£k) |
|---|---|---|---|
| SEWAMS | 3,380 | 0 | 3,380 |
| National PQM | 5,050 | 377 | 5,427 |
| Greenage WAM extension | 0 | 1,299 | 1,299 |
| National WAMS | 0 | 46,350 | 46,350 |
| **Total** | **8,430** | **48,026** | **56,456** |

*Table 1. System Monitoring Equipment schemes RIIO T1&T2 (CAPEX costs only)*

- Existing refurbishment is being covered in the P&C justification paper (NGET_A9.15 Protection & Control).
- The Power Quality Monitoring Scheme is rolling out harmonic detection across 110 sites. The units will be deployed by the end of T1. A central server and automated data polling is part of the scheme. The harmonic data for any of the sites can be accessed and used to identify issues or available headroom. This method will be the blue print for other monitoring applications. This provides the

benefit that the regular polling ensures the equipment is operating and where it is not, a work order can be raised to resolve the problem.

- The Network Innovation Competition (NIC) project VISOR has delivered a proof of concept WAMS using enhanced PMUs and new analytics to measure sub-synchronous oscillations associated with series compensation (£7m).
- The South East WAMS scheme is installing PMUs across 10 substations, a phasor data concentrator and associated applications to monitor the dynamic voltage stability and control interaction behaviour between the inverter fed connections across the region. This will be commissioned and be operational by the end of T1.
- The Greenage WAM scheme and completion of the PQ monitoring will further extend this scheme (£1.68m).

The end to end solution reliability is the key challenge. This requires dedicated and specialised resource to ensure the individual systems are operational and regularly tested to ensure remote polling, data retrieval and the archiving is working correctly.

## 4. T2 proposals

We are proposing to roll out an end-to-end system monitoring service over the whole regulatory period (March 2026). This is inclusive of:

- Installation of time synchronised measurement units, at all our GSP substations and regional PDCs (£[redacted]m + £[redacted]m).
- Establish a data collection system to back-haul this data into a central archive with analysis capability (£[redacted]m).
- Enduring support to deliver a reliable service to the end customers (£[redacted]m)

See Appendix 1 for further cost breakdown.

Three options for the provision of a National Wide Area Monitoring solution have been considered:

1. **Do nothing** – continue with the current level of equipment and observability. The ESO have already indicated this is not acceptable and without improving the wider system observability, the likelihood of more loss of supply incidents and wider scale disruption will increase. In particular, the lack of ability to provide adequate post event analysis for the whole network. Costs £1.68m, but will not achieve operational compliance.
2. **Full system Observability** – enhance data collection through the installation of new three phase measurement instrument transformers on most substation busbar sections (currently they only have a single yellow phase voltage transformer). Install new system monitoring equipment, plus the end to end data and analytical services. This will require major busbar outages and primary asset installation. This provides the highest level of accuracy and observability. Costs £99.7m to achieve operational compliance.
3. **Wide area observability** – This is a targeted solution, utilising existing instrument transformers and adding new system monitoring equipment plus the end to end data service to provide visibility at all GSPs. This minimises the need for major busbar outages and enables the release of most of the benefits, through the provision of a wide area monitoring solution. Costs £50.35m to achieve operational compliance.

The costs are composed of hardware installation (15yr lifetime), data support services (5yr refresh), analytical software (annual licence and updates) and the resource to manage and process the collected data into information. The installation costs are based on recent tender return costs from competent installers and schemes (VISOR, EFCC and SEWAMS schemes).

- A pilot scheme to modify SME units to also provide PMU data has been carried out to provide some basic PMU coverage. Following the refurbishment, it became apparent since the devices are of an older design, issues have arisen around the suitability of the operating systems, end to end communications and resiliency of service. These units will need to be replaced in T2 as part of the National WAMS.
- Some innovation and deployment schemes have been delivered in T1 (VISOR, EFCC, PQM, SEWAMS), so the costs and logistics to provide the hardware solution are established, but do not reflect resilient or hardened 'business as usual' support costs.
- Smartgrid solutions, rely significantly on Information Systems (IS) which introduce a large operational cost burden, in terms of telecoms services, licenses, analytics and technical personnel to deliver the value. This is necessary to providing a sustainable and effective service to support both our and the ESOs technical requirements.
- The analytics provision does not have an established cost base due to the innovative nature of the solution, although indicative costs from the NIC projects have informed the pricing.

***Delivery***

The ESO policy requires every GSP to be observable by the end of 2026 (end of T2).

- The roll out will require each GSP to be upgraded with new synchronised SME. The roll out will require a coordinated strategy, as this will be resource intensive to manage the installation logistics (drawing updates, method statements etc.) at every substation. Most of this can be offline, however where new connections to CT and VT wiring will be impacted, short outages will be required. This will be bundled with other ongoing light current upgrade or replacement work.
- Synchronised measurements cannot be extracted from the existing fault recorders or SCADA without major upgrading or modification, additional time synchronisation and bridging of the cyber firewall. This modification of operational protection and control will require security and settings configuration changes, requiring major network outages and increased risk of circuit un-availability.
- 80% of fault recorders are integrated into the protection relays and are not easily accessible for disturbance monitoring purposes.
- The data communications via RAMM is a critical factor in the improved access to SME, however further reinforcement is required to improve the resilience to SM equipment at site.
- Opportunities to derive the data from protection relays will only be feasible, where the full digital substation strategy (AS3) is being rolled out. This will implement the new IEC 61850 Process bus architecture using merging units to gather system monitoring data.
- SM is intrinsic to the delivery of Monetised Risk, Resilience and System Operability.
- At a substation level, there will be coordination between the various asset intervention schemes, particularly instrument transformer replacement, with regard to alignment of the measurement accuracy and availability of cores. Protection and control, particularly the fault recorder element, DSM, settlement metering and cyber security upgrades.
- Although SM shares a degree of commonality with condition monitoring, the opportunities to share infrastructure have been considered and included as far as possible in this submission.

***Risks of not delivering***

The SM strategy needs to be delivered as an end to end service, if the data collection and analysis is not provisioned and supported then the following issues will come to pass:

- We will not be complying with the STC-P 27-1, which could be considered a licence breach.

- We, and the ESO, will not be able to validate network models and increasingly struggle to model and understand the network adequately to reliably operate the system.
- The benefits to improve network optimisation will not be realised.
- There is no specific investment mechanism for wider SM roll out, since it is an enabler across the system rather than a specific scheme or boundary. This is essentially wider works to reflect the broader interaction between many assets and the way they are operated as part of a complex and interactive system.

**Case Study** *2003 US North East US blackout*

Major system disturbances result in significant loss of supply and if unchecked can cause a blackout. For example, the major 2003 North East United States blackout, resulted in 50 million people losing power for up to two days costing at least 11 lives and an estimated 6 billion US dollars. While this is a relatively low probability event, it is credible.

The Northeast United States and Canada Blackout (2003) took more than six months for a team consisting of tens of industry experts to get a full understanding of what had happened to cause the 2003 blackout.

Putting natural phenomena aside, the post event investigations indicated that two thirds of the smaller initiating incidents which resulted in blackouts may have been contained, if better network visibility and awareness had been available to inform and advise the control room of network performance prior to and post fault.

Amongst key lessons learned from the post-mortem investigation, was a lack of understanding of the transmission system, situational awareness (operator error) and inadequate real-time diagnostic support from the reliability coordinator. While there were other events which also contributed such as equipment failure and poor vegetation management, the lack of wider network observability most likely contributed to the cascading effecting following the initial fault.

Most of the large-scale WAMS deployments around the world have usually followed a large-scale blackout. This is evidenced in the US, India, China, South America and parts of Europe (Switzerland & Norway).

## 5. Stakeholder Engagement

This requirement has emerged as a result of the UK Government's drive towards a Low Carbon economy and the new *Net Zero by 2050* target. The change in the generation mix and proliferation of active new energy service providers, many of which are embedded in the DNO networks, is contributing towards a more complex and less predictable network.

Customers in general want a simple transparent connection, and expect the network companies (TOs, DNOs and ESO) to manage the network interaction, and to define the limits and operational envelope expected from energy providers.

The System Operator Transmission Owner Code (STC) Working Group is a key part of the Stakeholder engagement process, addressing the TOs and SO views. It is important to ensure network connectees fully understand their role in the network of the future and that monitoring services will play a key role in policing the Security & Quality of Supply Standards (SQSS) compliance.

Consumers and Stakeholders expect us and the ESO to employ reasonably practicable measures to avoid blackouts and major disturbances. It would be difficult to justify to a public enquiry or Select committee that, although such systems exist and are recommended by international best practice, we did not identify and agree a funding mechanism to install such measures.

Following consultation with stakeholders (via SOF publications) and the TOs, the ESO established a new System Performance Monitoring Policy. The consensus required the TOs to provide time synchronised measurements of current and voltage from all its GSP substations. This also aligns with the Government ambition to enable the digitalisation of power grids, such that new services can be identified and delivered providing consumer benefits. Stakeholder engagement has been addressed through the new STC working group (WG), which was responsible for the production of the new STC-P 27-1.

Further stakeholder engagement has been carried out through external dissemination events of the VISOR and EFCC NIC projects. In all cases, there is recognition that the provision of better network observability through PMU deployment is one of the key enablers to delivering the SmartGrid which can secure a reliable network and provide consumers with competitively priced energy.

A set of services are required to provide the ESO (the key customer) with a high degree of System Monitoring confidence. They want a service, not asset ownership. The SO is supportive of the T2 proposal and the costs associated with delivering and supporting a resilient service, which have been derived from ESO participated projects.

***Best practice***

Scottish Power already has comprehensive system wide coverage of their GSPs. The standalone monitors are multi-functional fault recording devices also capable of being firmware upgraded to provide phasor measurement capability. All the units are connected to a central server and automatically poll the data. This enables fast fault diagnosis, identification and location of disturbances and monitor status. Applications are being developed to automate the fault reporting and regular performance reporting. There is a small dedicated team to support the business and maintain the equipment.

## 6. Cost benefit

The key risk if we do not adopt a solution which provides better system visibility is the greater likelihood of wider scale blackouts. This is not necessarily because of its immediate presence, but the lack of ability to accurately model and predict network contingency and operating margins as we go forward.

While the probability of a large-scale blackout is remote, it is not zero, typically we will expect to encounter a major network related event every 10 years. This is likely to increase in the coming years as the networks become more complex and volatile due to the reasons explained earlier in this paper. This will have a massive economic impact on all consumers.

With better observability, there is the possibility to optimise and improve operability.

Further to underpinning resilience and meeting the STC-P 27-1 criteria, there are additional consumer benefits over the RIIO T2 period. This enhanced system observability can help to inform design decisions, control automation and secure the network under various contingencies. This will become more critical as the transmission network encounters more complexity, volatility, demand and generation uncertainty. The value of these benefits, summarised below, is difficult to estimate at this stage, but could feasibly amount to 10’s of millions per annum through reduced system operation costs alone.

- System Planning – understanding and insight from SM into scheme specifications can help to reduce connection scheme costs through better headroom and higher capacities. This is very scheme dependent and may require changes to standards.
- System Operation – using SM to validate and optimise models to better visualise system constraints, will help to improve boundary capability and reduce constraints.

- Where this is identified, any benefit or saving will flow through to the consumer through reduced constraint costs.

## 7. Managing Uncertainty

We have only included the most certain costs in our baseline plan and are proposing a suite of uncertainty mechanisms, set out in annex NGET_ET.21 Uncertainty mechanisms, that allocate risk to whomever is best placed to manage it.

Consumers can best manage uncertainty about the route to net-zero emissions because the route will reflect changes in their behaviour. We are best placed to manage uncertainty over costs of achieving outputs consumers want because can efficiently control our costs.

Costs and volumes of work for this category of expenditure are highly certain. All costs have therefore been included in our baseline plan and no uncertainty mechanism is proposed.

## 8. Conclusion

The rapidly changing low carbon generation mix and increasingly active distribution networks, requires both the ESO and transmission companies to improve their ability to operate efficiently under this massive network change in network behaviour.

The ESO policy STC-P 27-1 mandates that all the TOs shall install synchronised system monitoring at all their substations to improve the wider system observability by the end of T2. System Monitoring services are critical to validating the assumptions used in planning, operation and management of the Transmission System and its assets. SM provides information on disturbances, power quality and faults which will enable us to observe the performance of its assets and the network and can also identify risks and opportunities for the business.

An investment of £[redacted]m is sought to comply with this licence requirement and provide a resilient end to end supported service. This includes the installation of System Monitoring Equipment (SME) and the backhauling of data to a central system which provides the access, analysis necessary to observe and validate system performance.

The status of the existing system monitoring equipment is not adequate, requiring new synchronised monitoring equipment and automated data retrieval to deliver this service to a central place. Three options have been considered, the selected strategy provides a compliant approach which utilises existing plant and equipment where possible to minimise the cost and impact on network outages and deliverability.

If this work does not go ahead there will be an increasing risk that we, and the ESO, will not be able to reliability predict and detect issues which could lead to major network disturbances and major economic consequences for consumers.

# 10. Appendix 1 – Costs breakdown for T2 National WAMS.

| Item | 21/22 | 22/23 | 23/24 | 24/25 | 25/26 | T2 total |
|---|---|---|---|---|---|---|
| Substation System Monitoring Equipment - installed costs | [redacted] | | | | | |
| Data backhaul | | | | | | |
| Archiving & Analytic tools | | | | | | |
| **Capex total** | 9815 | 9369 | 9301 | 9716 | 9824 | **48026** |
| FTE - Analytics resource | 70 | 70 | 70 | 70 | 70 | **350** |
| spares, licenses, services | 225 | 275 | 325 | 375 | 425 | **1625** |
| FTE - maintenance & support. | 70 | 70 | 70 | 70 | 70 | **350** |
| **Opex total** | 365 | 415 | 465 | 515 | 565 | **2325** |
| **Totex total** | **10180** | **9784** | **9766** | **10231** | **10389** | **50351** |