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Network Innovation Competition Screening Submission Pro forma

Notes on completion

Before completing this form, please refer to the relevant Network Innovation Competition (NIC) Governance Document(s).[1]

Please use default font (Verdana size 10) in your submission and retain 1.5 line spacing.

We will only accept the text visible in the text entry areas.

The text entry areas are predetermined and should not be changed.

The full-completed submission should not exceed 19 pages in total.

Ofgem will publish all the information contained within this Screening Submission.

Is the application for the Gas or Electricity NIC? If a Cross-Industry Project, please state 'Cross-Industry'.
Electricity NIC
Funding Licensee
National Grid Electricity Transmission
Project Partners including other Licensees
In discussion
Project Title
Proteus – Virtual Synchronous Machine Compensation

[1] https://www.ofgem.gov.uk/publications-and-updates/version-30-network-innovation-competition-governance-documents All capitalised terms used in this document have the meaning given to them in the respective NIC Governance Document.

Project Summary
The rapid uptake of renewable generation is vital to the UK government's target of net zero greenhouse gas emissions by 2050. However, the associated shift towards a network with a lower proportion of synchronous generation presents an urgent challenge to security of supply. This is because characteristics vital to grid stability and operability, traditionally supplied by synchronous generators, are not inherent within renewable generation. This challenge will become increasingly acute in the next decade as the electricity system prepares for Zero Carbon operation from 2025 onwards, whenever there is sufficient renewable generation available to meet the total national demand. This project proposes to build a new type of transmission asset, the Virtual Synchronous Machine Static Compensator (VSM STATCOM). This solution can be optimally placed in the network to support grid stability through its transient real and continuous reactive power capabilities. Virtual Synchronous Machine (VSM) control is an innovative concept for use in the power electronic convertors, which enables them to behave like synchronous generation; helping to mitigate risks to security of supply. Integrating VSM capability into a static compensator (STATCOM) - which are currently used to alleviate voltage constraints in the network - will enable transmission assets to further contribute to alleviating stability and operability concerns; delivering a stable low carbon power system at a reduced cost. Project Proteus aims to develop, design and build a transmission-connected 50MVA VSM STATCOM in partnership with a supplier; building on recent research and development work and bridging the current technology gaps.

Estimated Start Date		**Estimated End Date**	
Q1 2021		Q1 2025	
Total Project Cost	£22 million	**NIC Funding requested**	£19.8 million
Technology Readiness Level (TRL) at start and end of project			Start:5 End:7/8

What is the Problem that the Project seeks to address?

Historically the GB network was designed to transmit power predominantly from centralised, transmission-connected generators to consumers. These generators are large, synchronous, continuously operating, dispatchable, and the majority are fossil-fuelled. However, to meet zero carbon operation, much more new renewable generation needs to be integrated in short timescales, and the traditional fossil-fuelled generators need to be phased out. This evolution requires a significant change to the way the system is operated, to accommodate generation that is often smaller, non-synchronous, and intermittent.

Three key challenges that the grid faces from high penetration of renewables are maintaining:

- **Grid forming capability:** permitting generators to operate in a black start situation or weak grids,
- **Inertia:** resisting sudden changes in frequency and providing torque to dampen oscillations in synchronous plant, and
- **Voltage regulation:** by the absorption or generation of reactive power.

NGESO relies increasingly on procuring balancing services to replace this grid support. This comes at a large and increasing cost, and, in the main, is still provided by fossil-fuel powered synchronous plants.

Today, over 60% of UK demand is provided by synchronous generators (~40% by fossil-fuel generators). However, as this proportion decreases, the system needs a way of replacing vital grid stability and operability support, or industry risks the following consequences:

- **Slow adoption** of low carbon generation and continued reliance on fossil fuels,
- **Significantly increased costs** to consumers and customers, and
- Increased probability of **power outages**

Whilst alternative grid support technologies do exist, there are several reasons why they have yet to be deployed on a large scale. Primarily, technical specifications for more advanced technologies are underdeveloped due to lack of grid-scale prototypes.

This project will develop the VSM STATCOM to support the grid by delivering Grid Forming Capabilities, Virtual Inertia and voltage regulation; reducing reliance on balancing services.

What Method(s) will be used and why? Ie, what is being demonstrated or developed? Please describe in terms of the NIC eligibility criteria. (page 1/3)

This project proposes to develop and demonstrate an Innovative solution which can provide crucial support to the network – the VSM STATCOM. This project will deliver a transmission connected VSM STATCOM into the network delivering valuable functionality to the system. The project will build on recent research and development to deliver a high-power grid capable system; bridging the TRL gap that currently exists.

The technology to be developed

The STATCOM is a power electronic device that provides voltage regulation services through reactive power compensation. NGET currently build and operate these devices to remove voltage and stability constraints in the network.

VSM is an advanced control strategy for driving the switching scheme of a power electronics-based converter. The VSM creates a stable voltage source in the network, unlike conventional converters that follow the voltage of the network.

The VSM STATCOM takes these two technologies and combines them into a single transmission asset, which can provide continuous MVAr support and transient MW support to the network. The ability to provide transient real power support comes from the integration of small energy storage elements into the device.

Whilst the STATCOM is a relatively mature technology, to incorporate VSM into its design several areas require development:

- Detailed requirements and application of VSM control to emulate the desirable characteristics of synchronous machines including grid forming capabilities in the transmission network.
- Coupling of the STATCOM with the most suitable energy storage devices to provide fast short-term active power injection/absorption into the grid, which supports grid frequency stability.
- Appropriately detailed transmission-system driven studies to determine strategic location and connection of devices, to provide maximum technical and cost benefits to consumers.

What Method(s) will be used and why? (page 2/3)

This project will build upon the work performed in the Grid Code Working Group GC0137 - "Minimum Specification Required for Provision of VSM Capability", feedback into this working group to disseminate key learnings, and crucially deliver on a main aspiration of this working group by building a grid compliant VSM STATCOM.

The project will capture the design, integration, testing and validation knowledge of a grid-scale VSM STATCOM that readies the technology for use on the network by relevant licensees and third parties.

How it solves the problem above

This project addresses the issues identified in the problem statement in several ways:

- By developing an alternative technology that can deliver Gird Forming Capabilities, support the network with Virtual Inertia and voltage regulation; a more resilient and competitive market can be established to deliver these services.
- The project will also demonstrate the benefits from delivering these through transmission assets; accelerating the adoption of renewables, maintaining security of supply and delivering savings to consumers.
- The project will also bridge an existing TRL gap in converter interfaced VSM technologies.

Why NGET

NGET have significant in-house expertise in VSM technology, close links with academia as well as active participation in the VSM Grid Code working group (GC0137), which we will marry with our knowledge of transmission system operation.

A NIC-driven grid scale demonstrator will help to bridge the technology TRL gap specifically for the GB transmission system, whilst the sharing of knowledge with stakeholders throughout the project will address the uncertainty in the market around the technical specifications for the implementation of VSM at grid-scale.

Scope – Project Workstreams

The project has been structured into five Workstreams:

What Method(s) will be used and why? (3/3)

- **WS1 Project Development:** finalise the requirements for the device, supported by offline modelling and simulation. Transmission system studies of VSM deployed at scale. Deliver detailed, transmission-system driven study of strategic location and connection, to provide maximum technical and cost benefit. Procure supplier transparently under Utilities Contract Regulations (UCR).
- **WS2 Design:** detailed design of VSM STATCOM including control scheme.
- **WS3 Installation:** Installation and commissioning of the STATCOM, and implementation of prototype VSM control.
- **WS4 Trial and validation:** Full integration of final VSM control > offline/acceptance testing > Hardware-In-Loop (HIL) testing to assess performance in undesirable scenarios > online test/live trial > validate operation of the solution.
- **WS5 Continued stakeholder engagement and knowledge dissemination.**

Funding Commentary (page 1/2) *Licensee must provide a commentary on the accuracy of its funding estimate. If the Project has phases, the Licensee must identify the approximate cost of each phase. If the NIC is being used as match funding, please state the other sources of funding.*

The NIC funding is being requested to fund the costs of development of the VSM STATCOM deployment according to the scope set out in the method. We propose the total project cost would be £22m, of which NGET are requesting £19.8m from the NIC funding, and NGET will contribute £2.2m. The estimated costs are broken down per workstream as follows.

Item	Cost (£m)	Confidence level
Workstream 1 - Project Development	2.5	+/- 10%
Workstream 2 - Design	15	+20/-20%
Workstream 3 - Installation		
Workstream 4 - Trial and Validation	4	+20/-20%
Workstream 5 - Stakeholder Engagement	0.5	+/- 10%
Total	**22**	**Approx. +/-20%**

The funding estimates are based on NGET's experience of delivering large projects and from existing information from previous projects. Equipment costs are based on an envisaged 50MVA, 400kV transmission-connected design, and have been supported by discussions with potential suppliers.

Funding Commentary (page 2/2)

The VSM STATCOM shall be strategically located within the England and Wales transmission network to maximise its contribution to system stability. The decision making on location will combine site specific factors and the ongoing ESO-led whole system assessment of system stability requirements. This will reduce other costs to the industry either in balancing costs or costs of other options to meet requirements. In addition to the long-term benefit to the consumer of technology de-risking, this brings an additional benefit from the NIC funds.

The project will review the decision to proceed at several key stages (or 'gates') within the programme. This will ensure that costs are kept under control and allow the underlying business case to be challenged and reviewed based on new learning from this project. Should the benefits case be seen to be no longer be valid, the project will consider closing and returning remaining funds to consumers. Clear definition of the requirements for passing gates will ensure a focus on delivery of value to stakeholders. This will limit the financial risk to consumers during the project's delivery.

Contingency has been built in to the costing to include expected variations in the costs from the market, variations to scope, and risks that are seen to be significant (e.g. currency variation and import taxes). The costed work breakdown will be refined with further stakeholder engagement in the Full Submission for NIC funding, which will improve our cost estimates.

The current split on spending will be reviewed for the full submission process. No additional funding sources are confirmed at present; however, NGET are engaging with other UK licensees and will seek opportunities for further support.

A clear and transparent UCR compliant procurement process will enable the best supplier in terms of cost and technical capability to be identified. We will weigh the assessment of the commercial aspects to maximise the value of the IP gained from the project (to be available to other network licensees). We will expect any supplier to contribute towards technology development activities from which they can derive future benefit in other markets. As the Project's focus is to design and build a demonstrator very specifically for GB transmission system operation, we do not expect it will be appropriate for the chosen supplier to wholly self-fund any aspects. NGET are also seeking value from attempting to leverage learning and knowledge from outside the UK, and will be assessing opportunities to do so as part of the full submission.

Which specific requirements does the Project fulfill?		
Mark YES in the appropriate box(es)	**Electricity**	**Gas**
A specific piece of new (ie unproven in GB) equipment (including control and/or communications systems and/or software)	**Yes**	
A specific novel arrangement or application of existing electricity/gas transmission and/or distribution equipment (including control and communications systems software)		
A specific novel operational practice directly related to the operation of the electricity/gas transmission and/or distribution systems		
A specific novel commercial arrangement		

How does the Project accelerate the development of a low carbon energy sector and have the potential to deliver net financial benefits to existing and/or future customers in the relevant sector? (page 1/2)

As presented in the problem statement, the challenges faced when trying to develop a low carbon GB energy sector can be classified as follows:

1. **Enabling increased renewable generation.** Connection of renewable generation, as discussed, is associated with stability and operability challenges. As a consequence, low carbon generation rollout may be delayed due to concerns of both grid-wide frequency stability and localised voltage stability.
2. **Retiring carbon-intensive generation.** To avoid stability and operability challenges, currently practices require maintaining certain quantities of synchronous generation, which is carbon-intensive. This raises the average carbon intensity of energy generation in GB.
3. **Maintaining security of supply.** Grid frequency and voltage levels need to be maintained within limits at an acceptable cost to consumers. Failing this, GB risks increased probability of power outages in response to changes in generation mix.

The Proteus Project will accelerate solutions to each of these aspects. The long-term **deployment of renewable energy** will be accelerated by the VSM STATCOM, as they

Accelerates the low carbon energy sector (page 2/2)

replace the desirable characteristics of synchronous generation.

According to FES 2019 net zero modelling, the proportion of converter-interfaced wind and solar connected to the GB network will increase from approximately 30GW in 2018 to over 125GW in 2050. Over the same period, the amount of synchronous generation (including CCGT and nuclear) will decrease from 60GW to 20GW. The VSM STATCOM will enable the operation of a higher percentage of renewable, non-synchronous generation by providing the desirable characteristics of synchronous generators as follows:

- The VSM STATCOM can respond rapidly to changing grid conditions in order to maintain security of supply. This includes the provision of virtual inertia to maintain grid frequency in response to system faults and other events.
- The reactive power absorption and injection can be continuously and automatically adjusted to manage system voltage levels.
- The VSM control methods are based on a different control algorithm (without relying on a Phase locked Loop (PLL)) which means it can operate in low synchronous generation systems and black start scenarios; as opposed to most non-synchronous generation which is based on control systems which use a PLL.
- The VSM STATCOM can support black-start capability and help with network restoration.

By enabling the progression of the VSM STATCOM to market, the roll-out of this technology across GB will accelerate the **timely retirement of carbon-intensive synchronous generators** and the **acceleration of renewable generation connecting to the electricity network** without affecting the security of their supply.

Development and demonstration of the VSM control methods at grid scale will benefit both Transmission and Distribution Licensees, as well as providing future market confidence to other players of the system such as generators and third-party service providers.

How will the Project deliver value for money for electricity and/or gas customers?
This Project delivers against the following three key customer values: 1) Low/zero carbon energy 2) Cheap energy, and 3) Power as and when it is needed – as described below: NGESO spends over £150m per year on balancing services for voltage regulation. This generally involves requiring synchronous generators to operate and absorb/inject reactive power, which has a large cost both to the consumer and environment. Additionally, in recent years NGESO has incurred significant Balancing Mechanism costs to curtail wind generation and procure synchronous generation due to rate of change of frequency (ROCOF) constraints related to low inertia. In response to these rising costs, NGESO has procured 12.5GVAs of inertia through Phase 1 of its Stability Pathfinder at a cost of £328m over 6 years, not including the cost of losses. By delivering the same operability and stability support, VSM STATCOM technology will reduce dependence on the costly services above. Moreover, it will do so with lower total operating costs than technologies that provide similar functionality, such as synchronous condensers. The lower cost is possible due to the much lower losses and maintenance costs for STATCOMs compared to synchronous condensers, with increased capital costs but lower TOTEX costs. We expect that the VSM STATCOM installed in this project will deliver a positive net present value to consumers over its lifetime. This unit will deliver the grid benefits for a lower total cost than relying on balancing services. Over a longer time horizon, the technology developed as part of this project will provide a lower cost alternative to synchronous machines and condensers providing essential grid services. The costs of providing VSM STATCOM units will decrease with economies of scale as they are rolled out more widely, while at the same time the costs of synchronous generators providing equivalent services increase with smaller numbers of older units. As a transmission asset, the VSM STATCOM can be installed wherever the grid requires support; providing better value for money to consumers compared to alternatives. Additionally, the same VSM control features that will increase in technological maturity as a direct result of the project can be used to give wind and solar farm converters the useful characteristics of synchronous machines, further reducing the need for additional stability and operability services.

How will the Project generate knowledge that can be shared amongst all relevant Network Licensees?
Knowledge creation and capture • Functional specifications will be written for the technical performance of VSM enabled STATCOMs, considering stakeholder input. These specifications are a critical element of the value chain for consumers and without them the consumer will carry the financial risks from rapid adoption of this technology. • The demonstration of VSM STATCOM functionality at transmission power levels will provide critical insights into operational considerations of these technologies that are not possible with desktop studies or laboratory prototypes. This will identify gaps and unnecessary requirements in the specifications to be removed sooner, accelerating the technology's adoption while also reducing risks for suppliers and consumers. For NGESO, this will lead to contributions to their VSM grid code (GC0137). • These two factors will help to define the criteria for a competitive and attractive market for all suppliers who wish to operate in this area. These specifications can be co-created with all licensees to enable the connection of VSM STATCOMs throughout the network; enabling all licensees to help accelerate our low carbon future. **Stakeholder engagement** • The project will include regular and structured stakeholder engagement, allowing licensees and stakeholders to gain and share insights from first-hand knowledge of the specification, design and installation of these systems. • Workshops will be setup to ensure stakeholders have a chance to input into the project's delivery and outputs. There will also be bi-annual meetings for stakeholders to receive project updates. The NGESO will be a key stakeholder and will be invited to understand the technology in detail and see how this technology can provide advantages over alternatives. We are working to formalise this partnership on the project. • The project will also communicate with the wider public through conferences and talks. Journal papers and industrial reports will also be published from the project's findings. We see this project as a great opportunity to deliver value in a collaborative manner.

Answering Yes or No, does the Project conform to the default Intellectual Property Rights (IPR) arrangements set out in the NIC Governance Document? *If answer is NO, the Licensee must demonstrate how learning will be disseminated to other relevant Licensees and how value for money will be ensured. The Licensee must also outline the proposed alternative arrangements and justify why the arrangements are more suitable than the default IPR arrangements.*
Yes. We understand that there is an important need to manage the IP generated from this project; we are very keen to ensure that our and consumers' investments into the IP enable a future where all stakeholders can benefit from the development of this technology. We will outline the NIC IPR arrangements clearly as part of our procurement process and we will seek to manage IP in the best interest of consumers. Should we find that through our tender process there are specific instances where we need to deviate from the standard IPR position; we will consult with Ofgem directly to understand if this is an acceptable deviation. We will also be engaging in dissemination throughout the project to ensure that learnings can be adopted by the industry and that licensees directly benefit from the technical learning that will come from this project.

How does the project demonstrate it is innovative (ie not business as usual) and has an unproven business case, that the innovation risk warrants a limited Development or Demonstration Project to demonstrate its effectiveness?

This project is innovative for the following reasons:

- It will develop and demonstrate a new technology in the GB network: the VSM STATCOM. This will be the first grid-scale VSM capable STATCOM deployment in the UK.
- It will develop novel control for the power electronic converters, in this case a STATCOM, using VSM principles.
- It will be the first STATCOM in the UK able to provide active power support and damping torque.

The business case rests on the assumption that the functionality of the VSM STATCOM can be delivered as expected both technically and commercially. The demonstration of this business case at transmission scale has not been proven in GB, and this presents a risk that is too large for network licensees or technology suppliers to develop without innovation stimulus. NIC investment into its demonstration will unlock a more competitive market and keep the costs of balancing the network down.

The innovation risks of the VSM STATCOM project can be classified as follows:

- **Technical:** No previous application of VSM to a grid-connected asset in the GB network. There is relatively little understanding of controller interactions with other power electronics devices and synchronous machines.
- **Commercial:** The CAPEX and OPEX are estimated based on supplier estimates, to be confirmed by the project.
- **Regulatory:** The VSM Grid Code requirements are under development and will need to be taken into account by the project.

These risks will remain in the marketplace until consumer investment occurs. Investment through the NIC mechanism provides better value for money for consumers accelerating the reduction of these risks in a transparent manner.

How were Project Partners, external resources/funding identified, and what are their respective roles in the Project? Please evidence how Partners were identified and selected, including the process and rationale that has been followed. *The Licensee should provide details of any Project Partners who will be actively involved in the Project and are prepared to devote time, resources and/or funding to the Project. If the Licensee has not identified any specific Project Partners, it should provide details of the type of Project Partners it wishes to attract to the Project.*
The project plan includes time to perform a clear and transparent UCR compliant strategic procurement process to identify a suitable supplier for the demonstrator equipment. This will enable the best supplier in terms of cost and technical capability to be identified, ensuring that the consumer still obtains value for money during the NIC project's delivery. Other TOs have been contacted and have expressed interest in remaining actively engaged throughout the project, and NGET is working to include other licensees into the project. NGESO believes VSM has the potential to play a significant role in driving the transition to a low-carbon energy system and has invested significantly in its own innovation programme to understand and test the technology. We have spoken to ESO about collaborating in this project and they are keen to explore this further during the Full Submission stage. Part of the project includes engagement with academic partners, and initial discussions have already begun during the ISP stage to help scope the requirements for the Project. The procurement of the R&D services will conform to UCR. Where engagement has already been made, these engagements have been made with no commitment and have not been specific enough to provide any contractor with a competitive advantage.

Would the Project require any derogations or exemptions to current regulatory arrangements? *If YES, please provide details of the required changes.*
No. This project has been designed to ensure that we stay within our existing licence. STATCOMs are transmission owner equipment. This project involves the storage of energy in electrical form. However, the Ofgem adopted definition of storage, as per the Energy Storage Network (ESN) (Ofgem, 29 Sep 2017, "Clarifying the regulatory framework for electricity storage") is not intended to cover network equipment whose primary function is not the storage of energy. The primary function of the VSM STATCOM is not energy storage; instead it is the provision of stability and operability services, for which a small amount of energy storage is required.

How will the Project activities impact customers? *The Licensee should outline any planned interaction with customers or customers' premises as part of the Project, and any other direct customer impact (eg amended charging arrangements, supply interruptions).*
This project does not require any direct interaction with customers since no work will be carried out on customer sites, and there is no requirement for long outages. The online demonstration and testing of the VSM STATCOM in the later stages of the project will only occur once sufficient confidence has been built through the earlier project stages, including modelling and offline hardware in the loop testing. The outstanding technical risk around interaction with other local converter-interfaced generators and synchronous machines will be mitigated by including the proximity to generation assets in the decision on siting of the VSM STATCOM. Furthermore, open and transparent communication will be held with owners of nearby generation assets to ensure that ongoing risk is clearly communicated and proactively managed.

This question is for Cross-Industry Projects only. What funding is being requested from each NIC? Please include justification for the funding split.
This is not a cross-industry project.

Are there any further details the Licensee considers would support its submission?
Innovative solutions are required to deliver future networks due to the increasing penetration of renewable energy sources. The VSM STATCOM offers a great opportunity to deliver value to customers, but investment is required to mitigate the outstanding risks of the technology. Investment through the NIC mechanism will minimise the cost to consumers and address the risks of the technology in a transparent manner. Compared to synchronous condensers and hybrid synchronous condensers (such as Project Phoenix), the VSM STATCOM promises several advantages. First, this technology is predicted to have significantly lower cost over the asset's lifetime, primarily driven by lower losses of the STATCOM compared to the synchronous condenser. Second, the VSM STATCOM can significantly support system stability as well as operability with capabilities such as virtual inertia contribution and voltage regulation. Third, as this is a transmission asset its enables better value to be delivered to consumers through strategic siting, as investments in the network can be made on their behalf. This project will adopt the learnings from the research in the VSM area led by the NGESO (see below) and, the Grid Code Working Group GC0137 – 'Minimum Specification Required for Provision of VSM capabilities' has been set up aiming at including VSM capability function specifications in the GB Grid Code. • NIA project (NIA_NGET0106) on system stability, protection and control challenges. • Multiple NIA projects (NIA_NGET0106, NIA_NGSO0004 and NIA_NGSO0019) demonstrated physical implementation of VSM and benefits of VSM converters in system stability and operability. • Ongoing NIA project (NIA_NGSO0026) on demonstrating VSM control of a battery system. A grid scale VSM-STATCOM does not currently exist, and while learning can be adopted from the small-scale prototypes, this project will take the essential step of scaling the technology and bridging the technology gap to meet grid requirements. The generation and capture of knowledge of deployment of grid-scale VSM STATCOM is a key part of the Project. Furthermore, stakeholders will be engaged throughout the project's lifetime and knowledge will be shared with them, leading to an eventual increase in competition and a lower overall cost of energy to consumers.

Contact Information (Cross-Industry Projects can provide two contacts)

Contact Name(s) and Title(s)
Paul Gallagher – ET Innovation Manager
Contact Address(es)
National Grid Warwick House **Warwick Technology Park, Gallows Hill,** **Warwick CV34 6DA**
Email address(es)
Paul.gallagher@nationalgrid.com,
Direct Telephone
Paul Gallagher - 07786 126 789